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(12) **United States Patent**
Lu et al.

(10) **Patent No.: US 7,840,109 B2**
(45) **Date of Patent: Nov. 23, 2010**

(54) **FACTORY SPLICED CABLE ASSEMBLY**

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(73) Assignee: **ADC Telecommunications, Inc.**, Eden Prairie, MN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 156 days.

(21) Appl. No.: **12/180,670**

(22) Filed: **Jul. 28, 2008**

(65) **Prior Publication Data**

US 2009/0022460 A1 Jan. 22, 2009

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/837,862, filed on Aug. 13, 2007, now Pat. No. 7,454,106.

(60) Provisional application No. 60/976,054, filed on Sep. 28, 2007, provisional application No. 60/950,521, filed on Jul. 18, 2007, provisional application No. 60/837,481, filed on Aug. 14, 2006.

(51) **Int. Cl.**
G02B 6/44 (2006.01)

(52) **U.S. Cl.** **385/114**; 385/100

(58) **Field of Classification Search** 385/100–114
See application file for complete search history.

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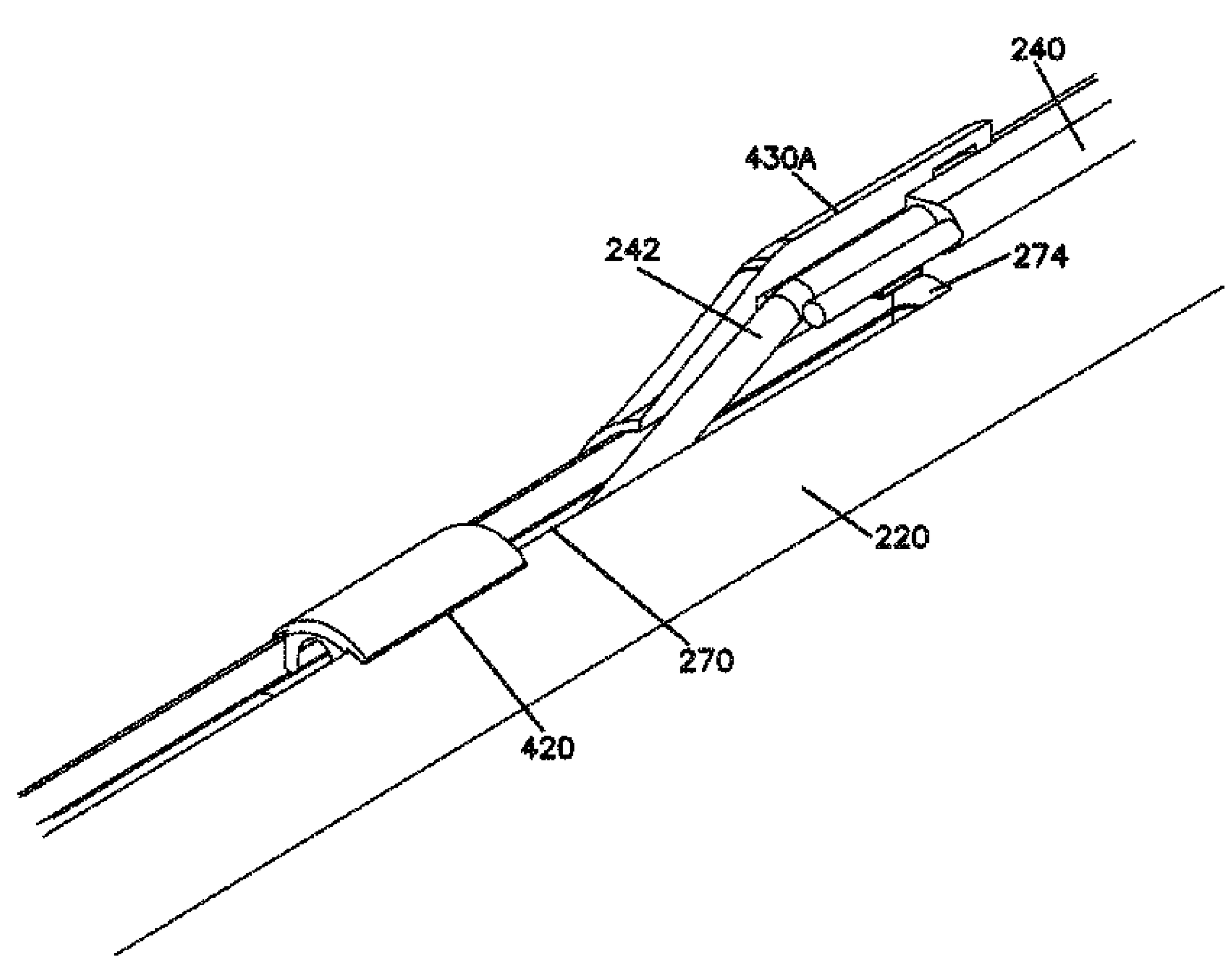
(57) **ABSTRACT**

A telecommunications cable including a main cable having a central buffer tube enclosed within a cable jacket and a ribbon stack positioned within the buffer tube. The main cable includes a cut region where a slot has been cut through the cable jacket and the buffer tube to provide access to the ribbon stack during manufacture of the telecommunication cable. A tether branches from the main cable at the cut region. The tether includes an optical fiber that is optically coupled to an optical fiber of the ribbon stack.

11 Claims, 38 Drawing Sheets



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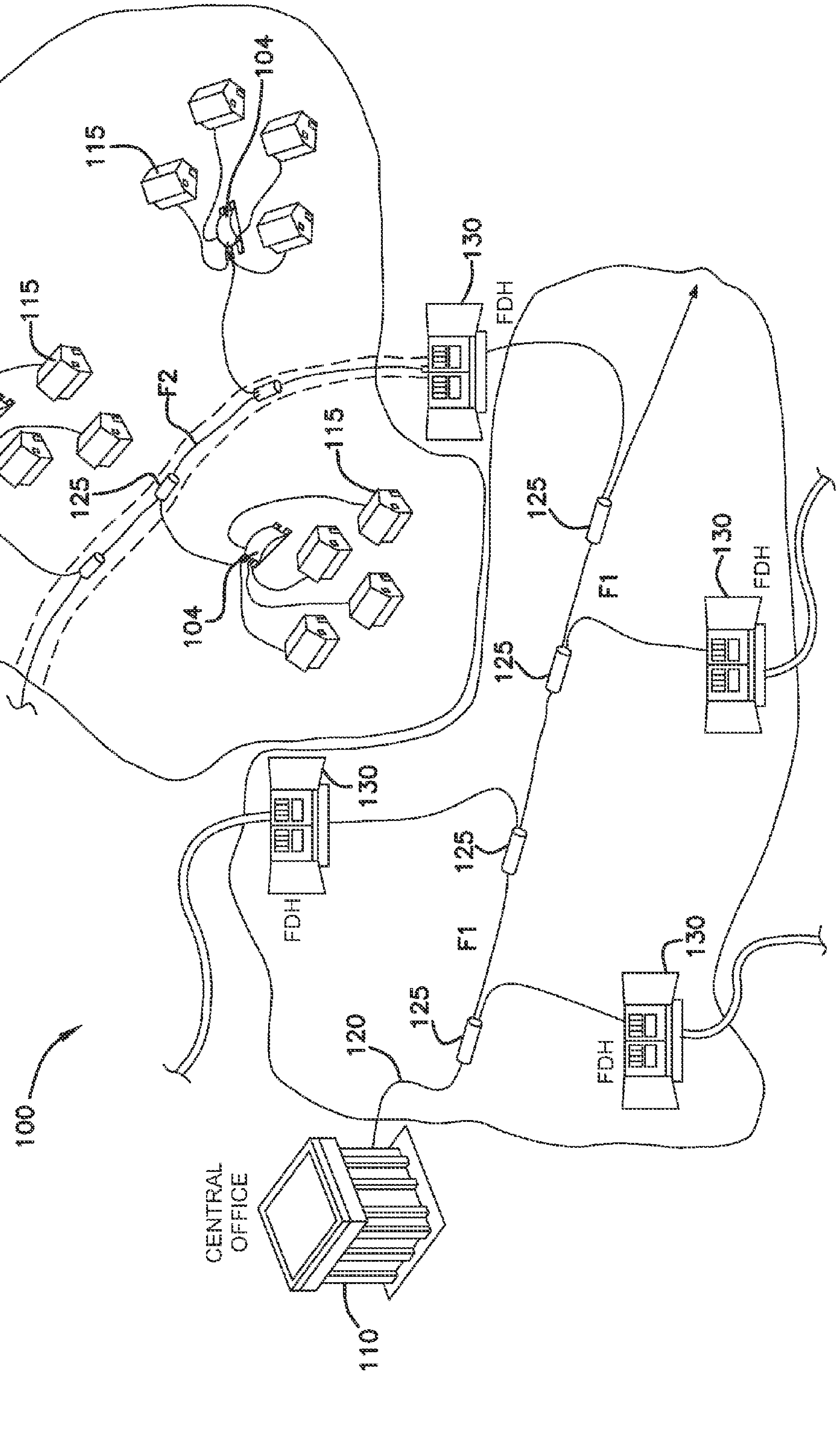
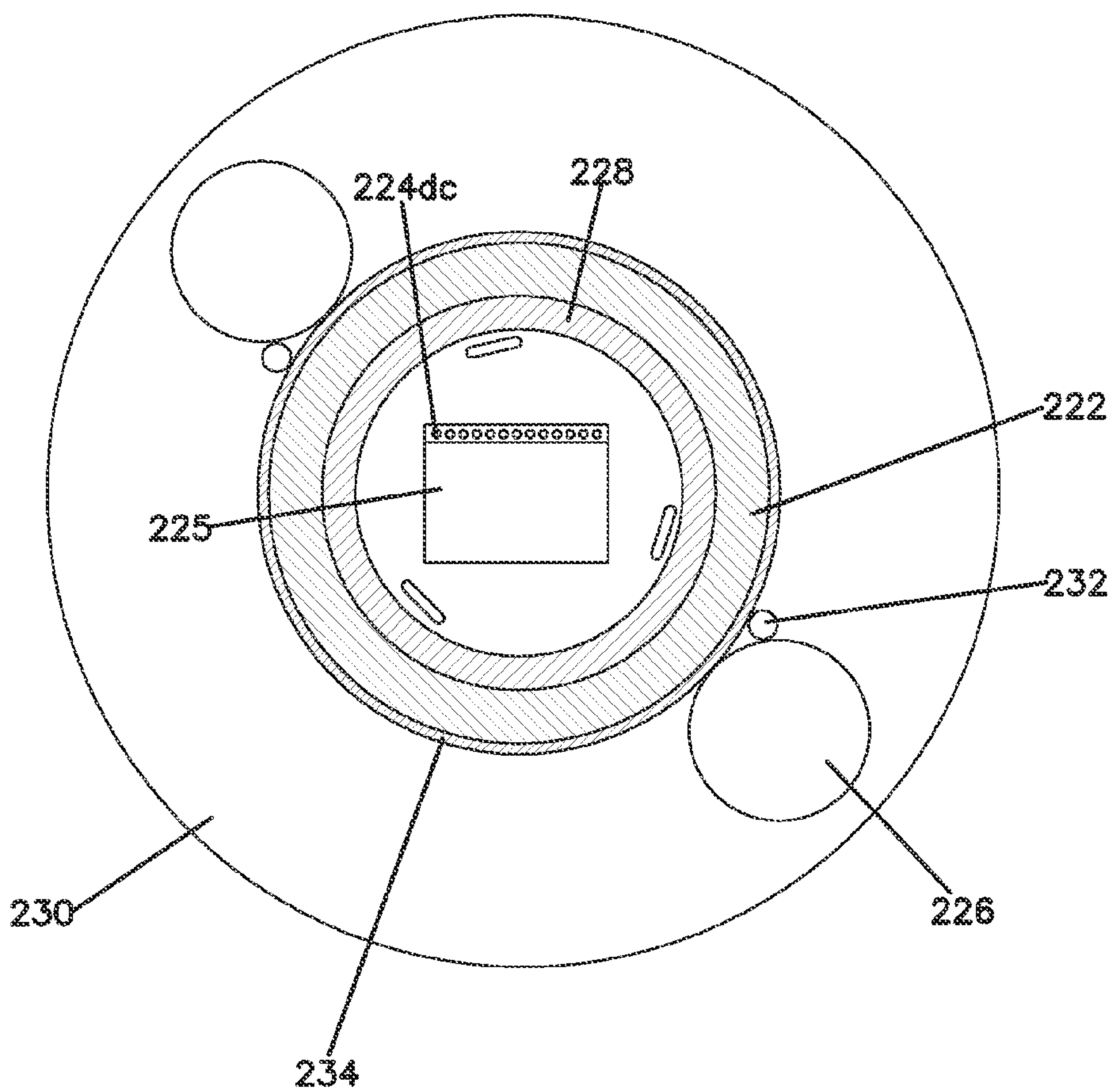


FIG. 1
(Prior Art)

FIG. 2



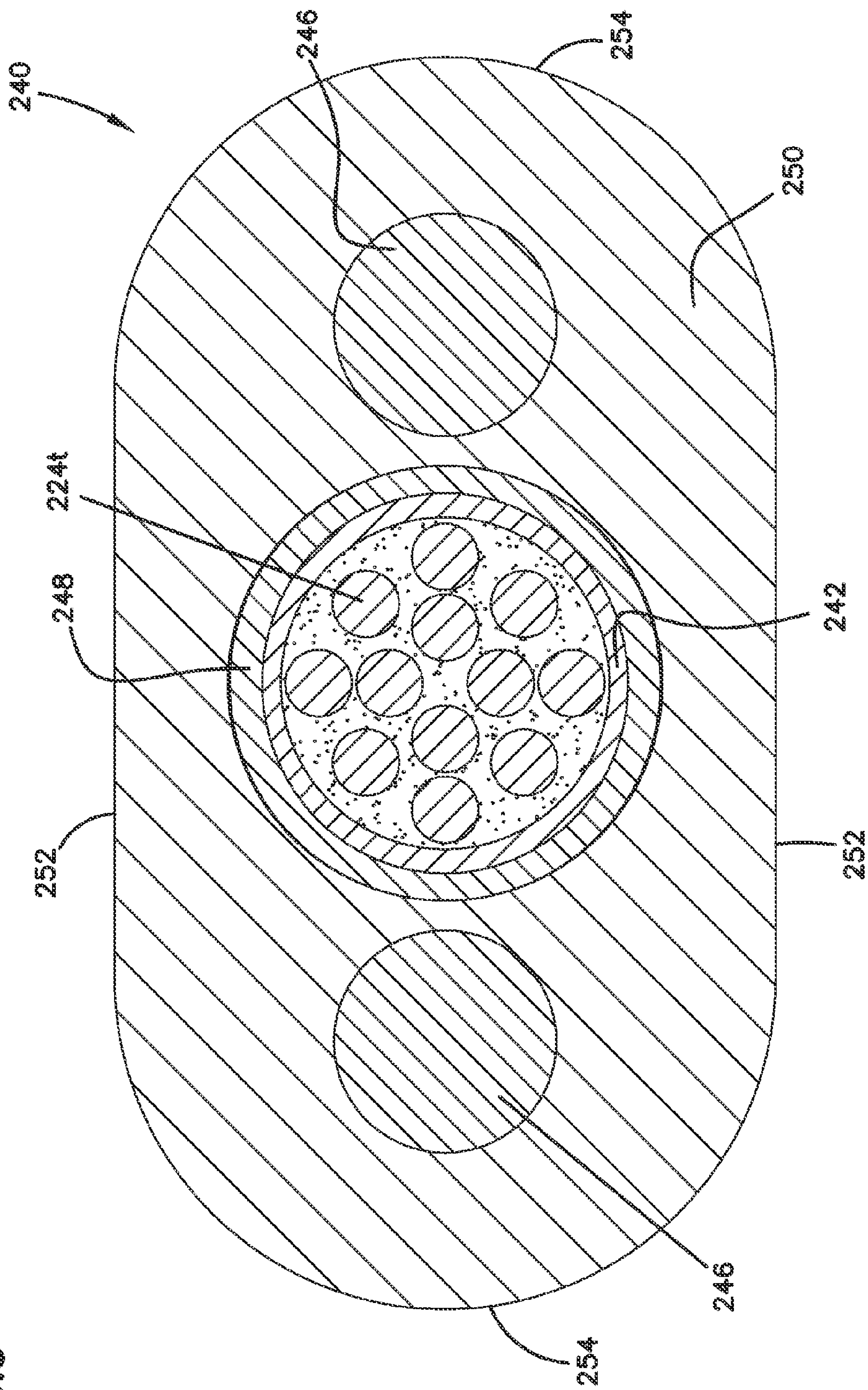
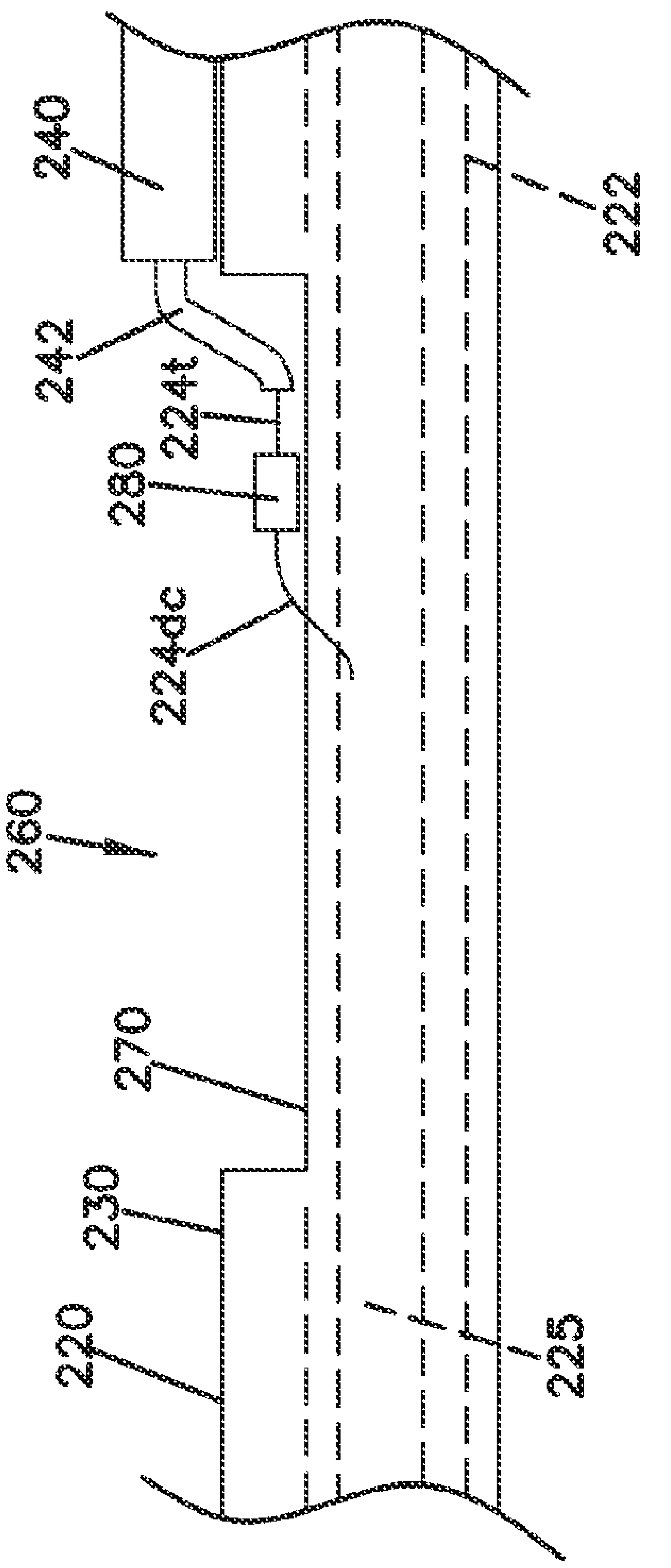


FIG.3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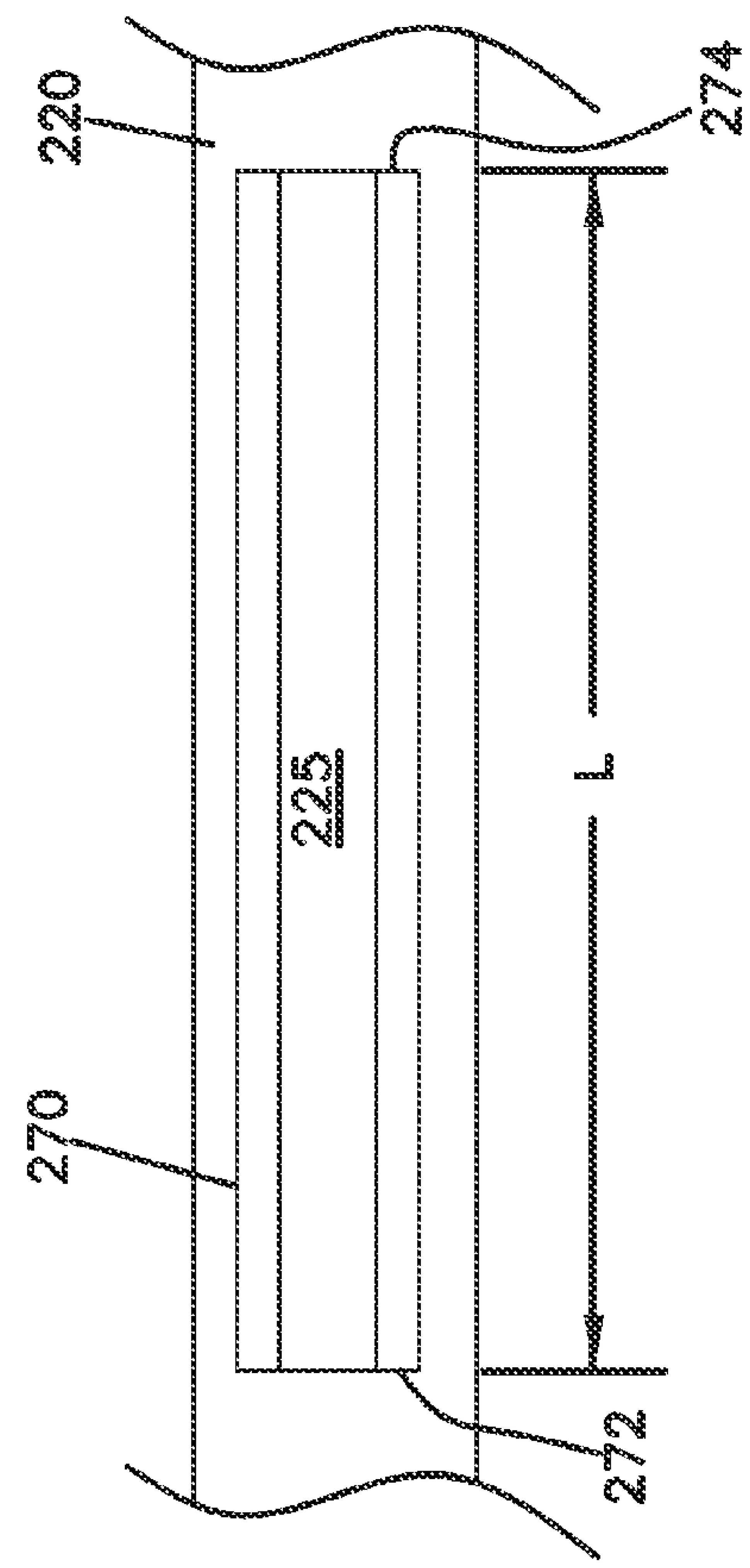
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FIG. 5

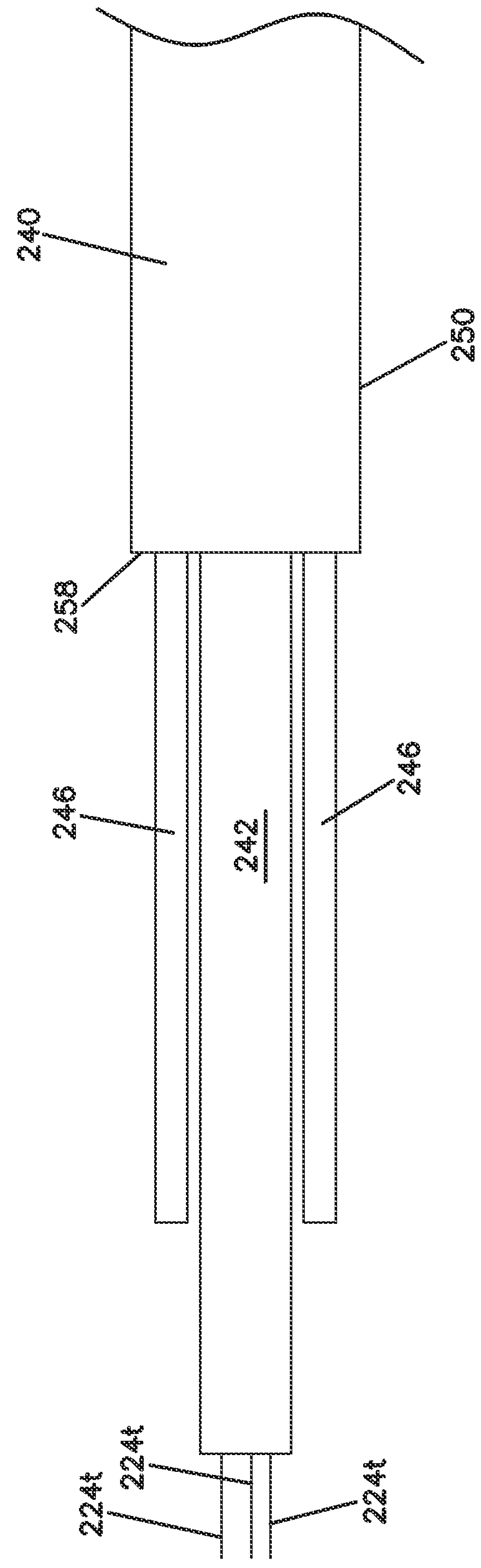


FIG. 6A

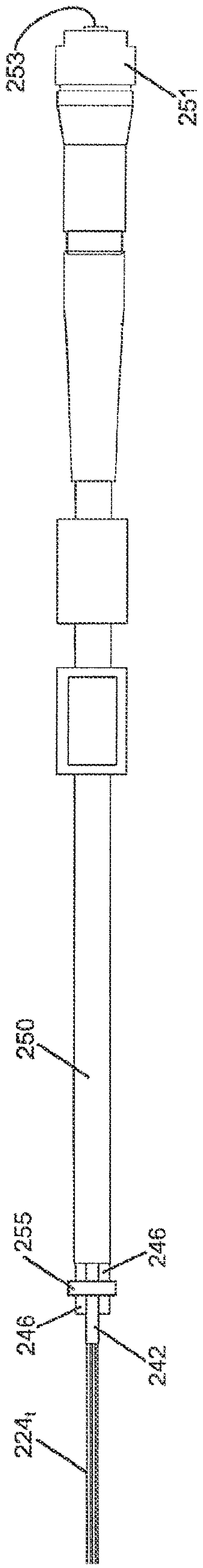
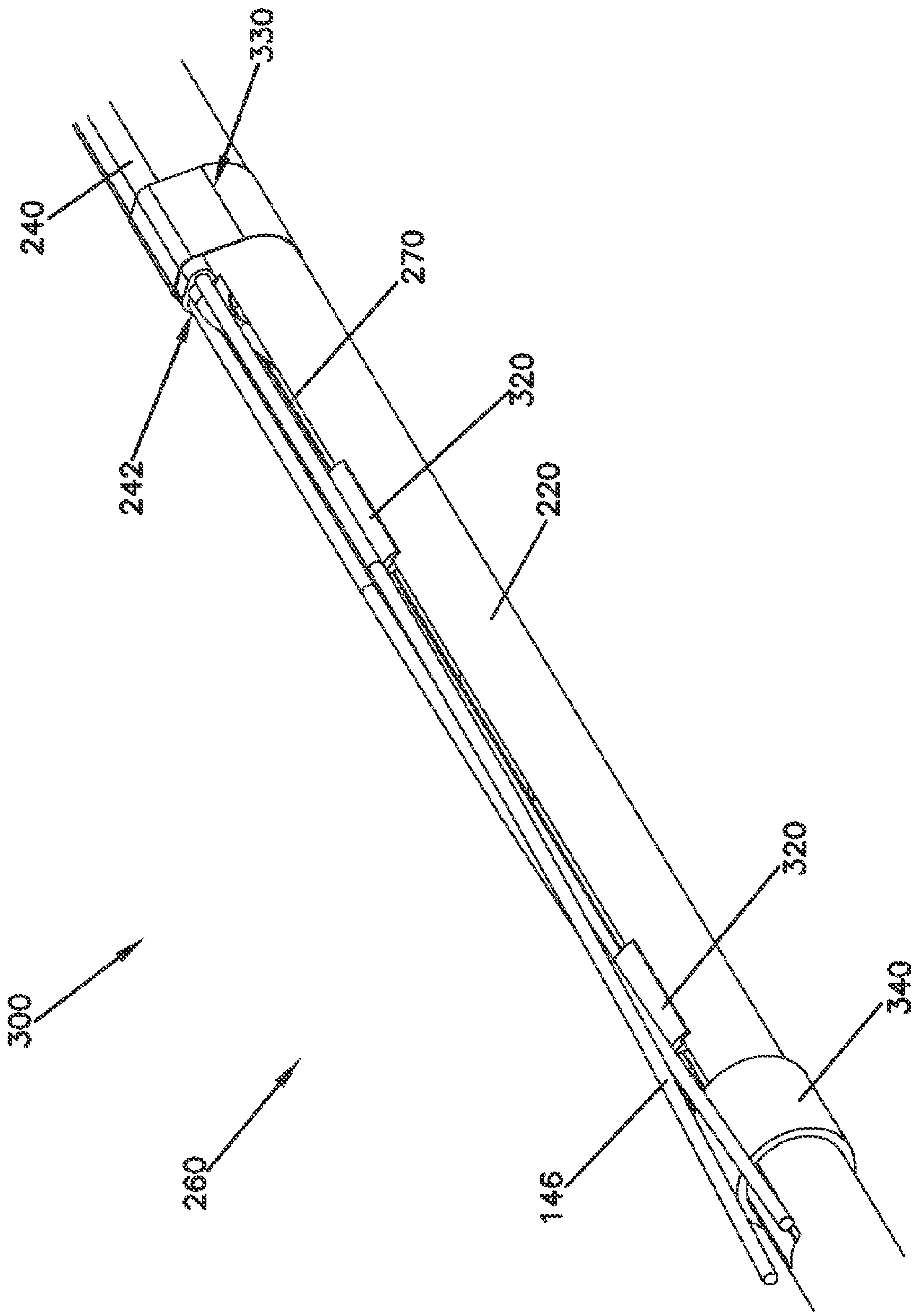


FIG.6B



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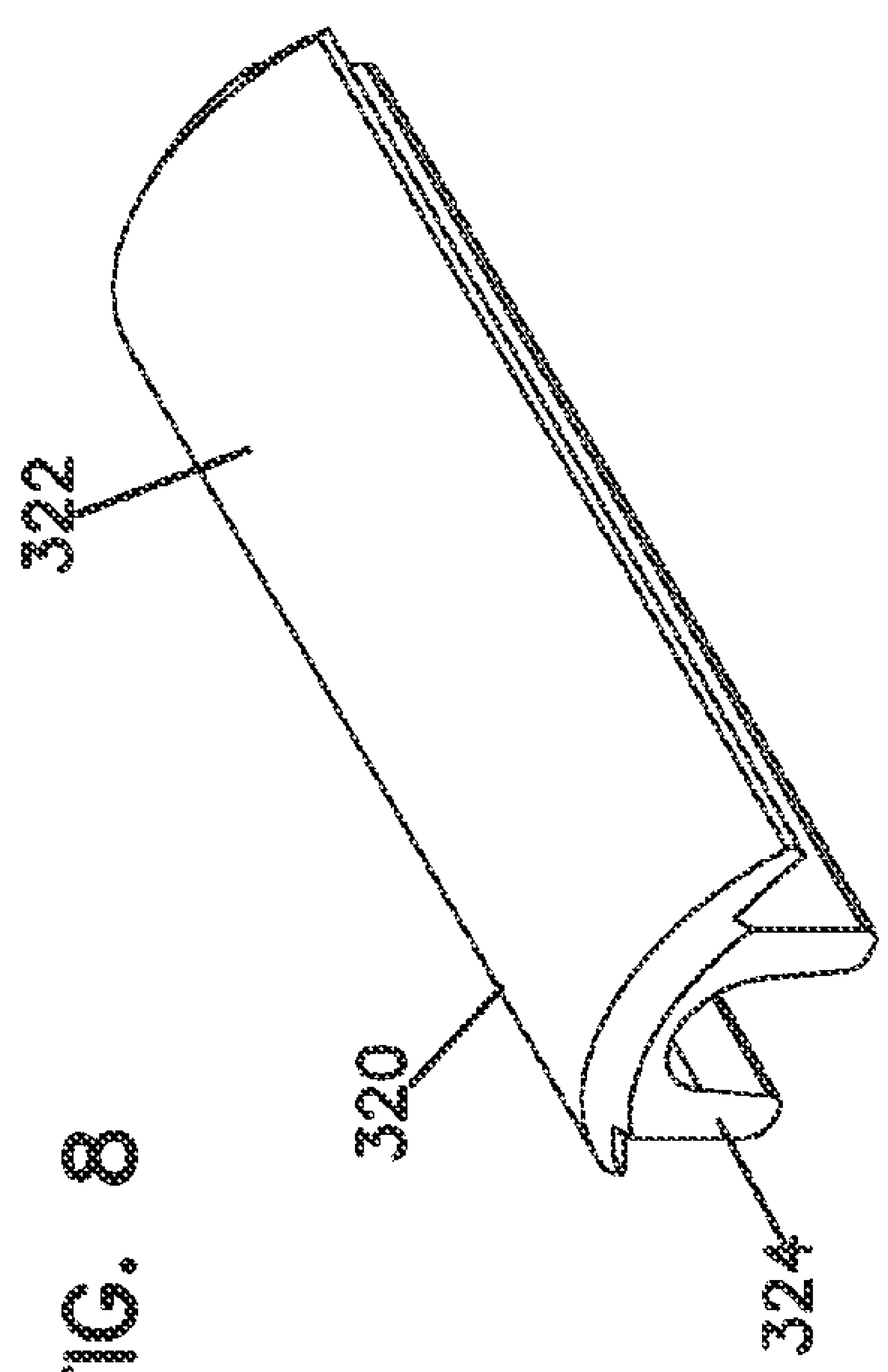
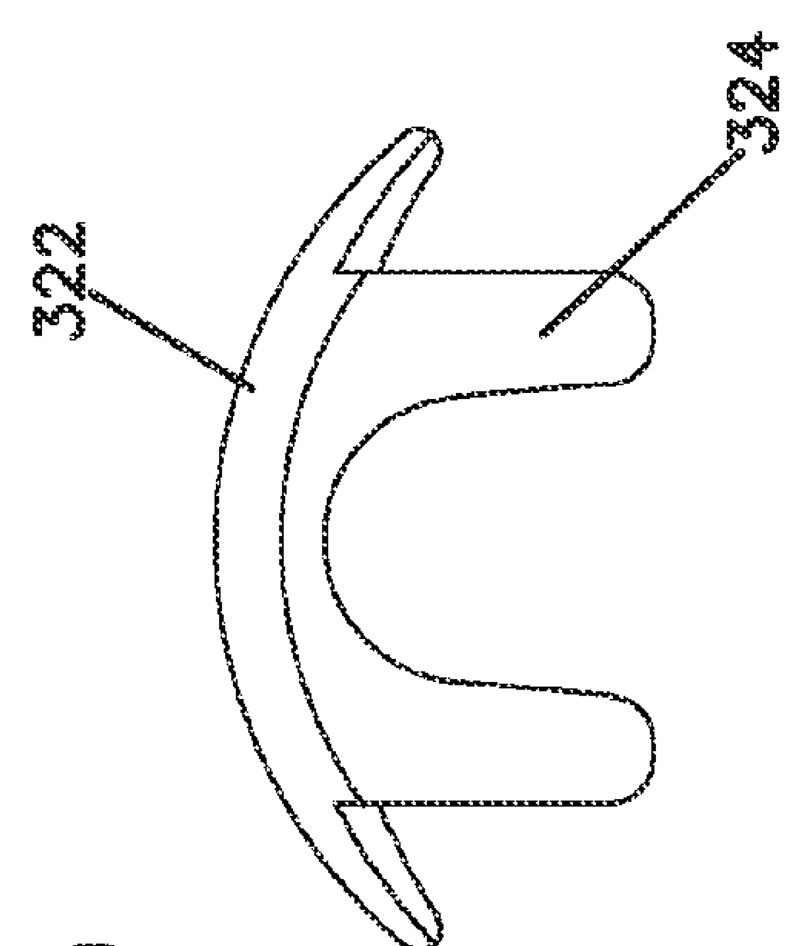


FIG. 8



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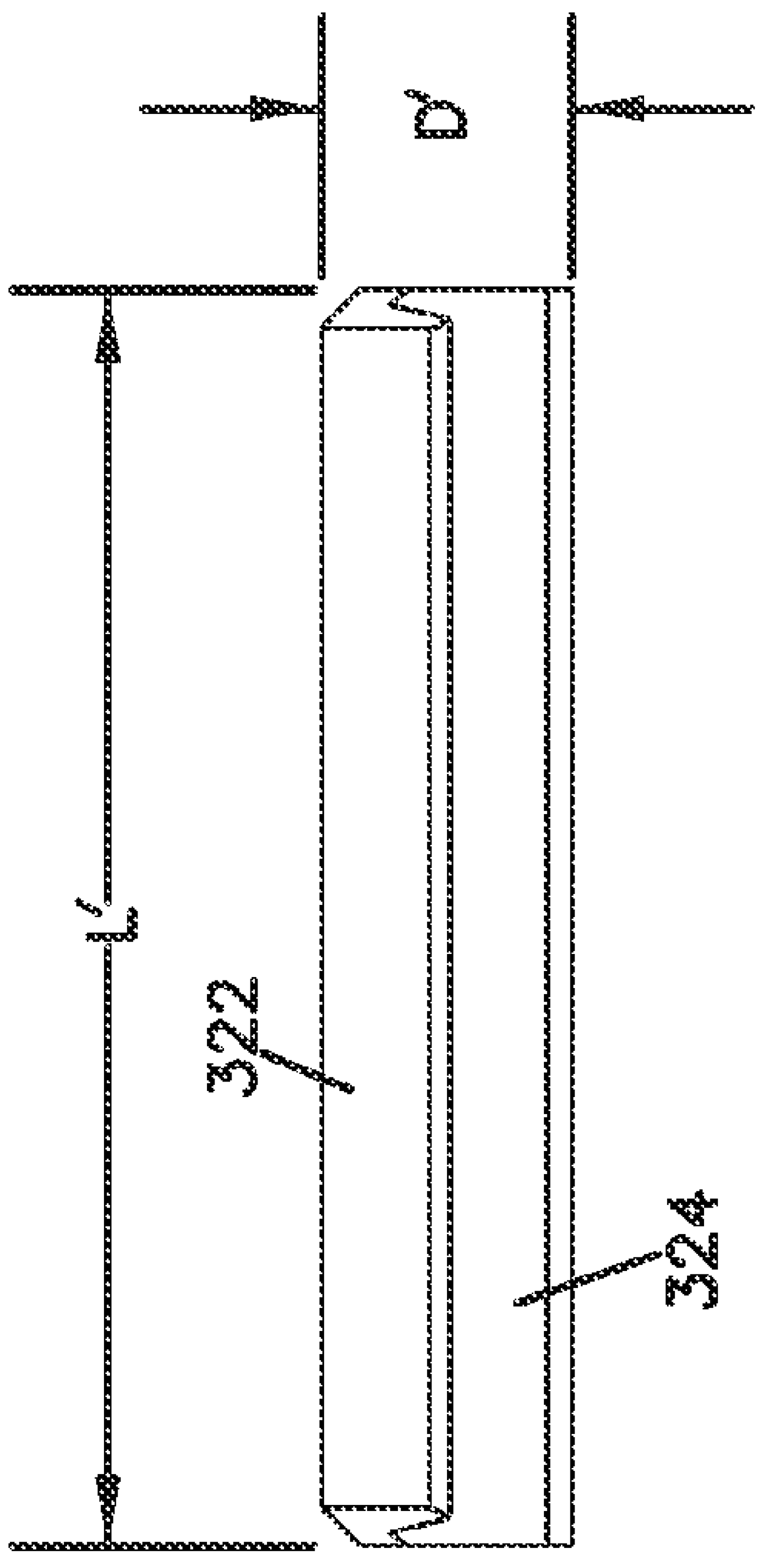

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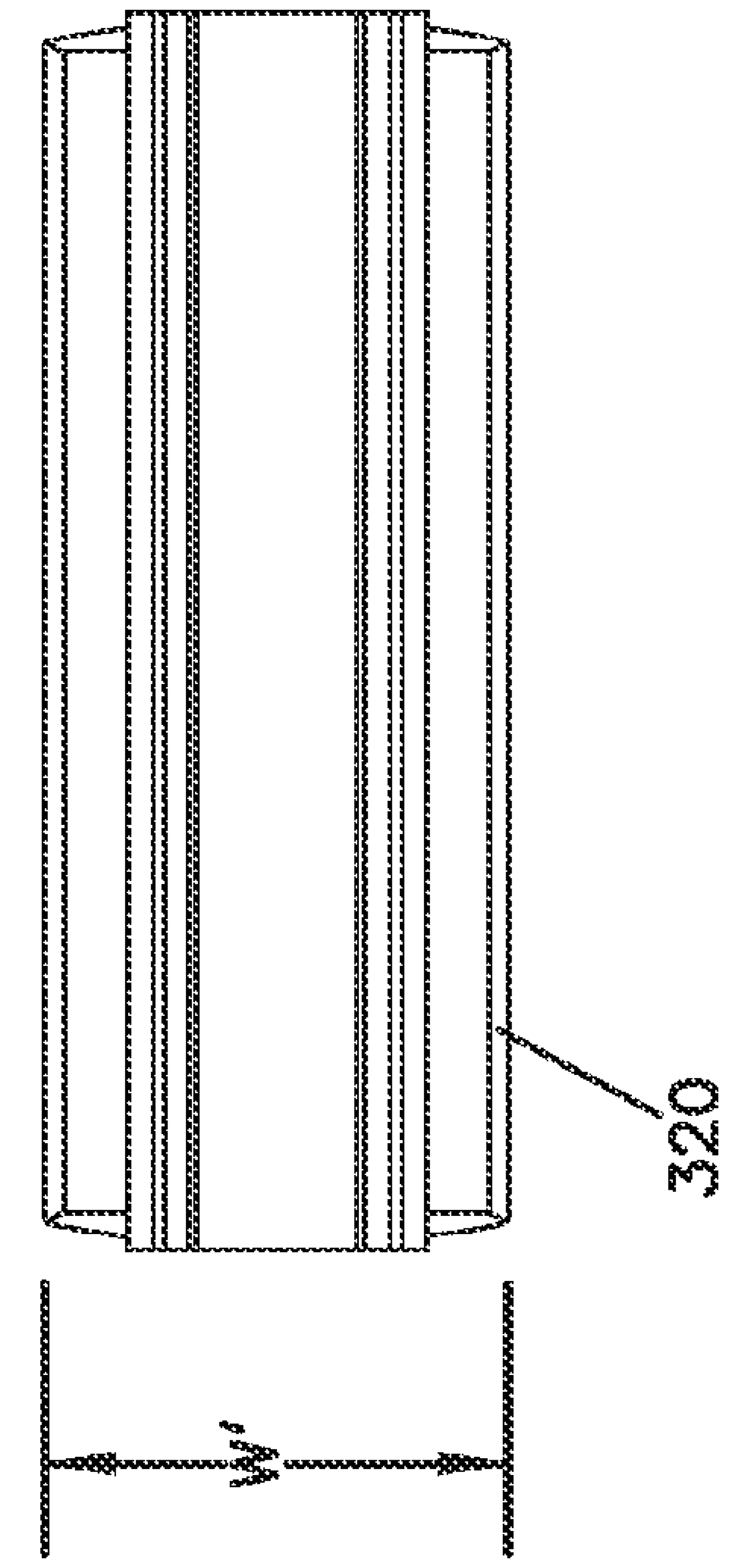

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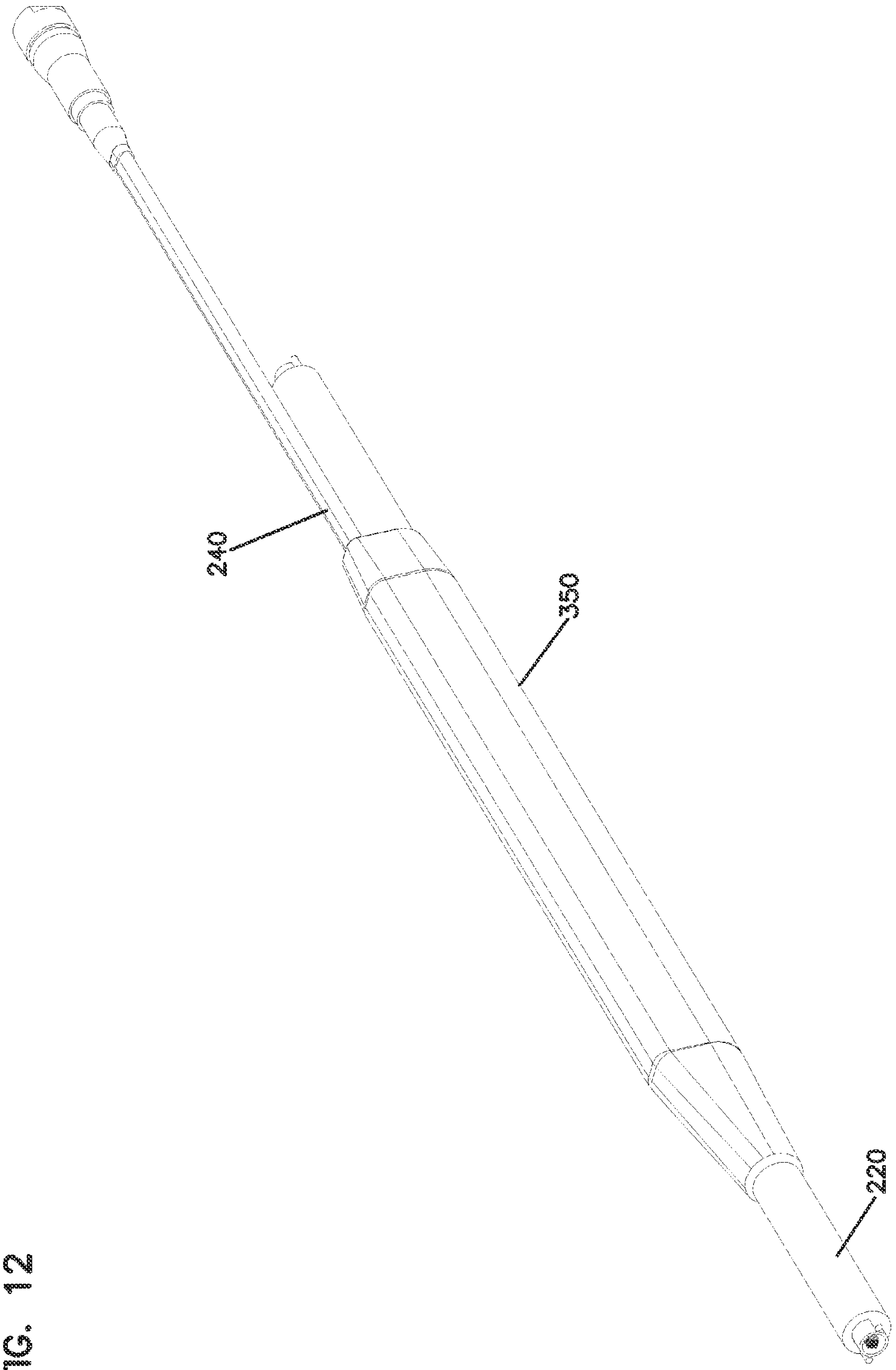

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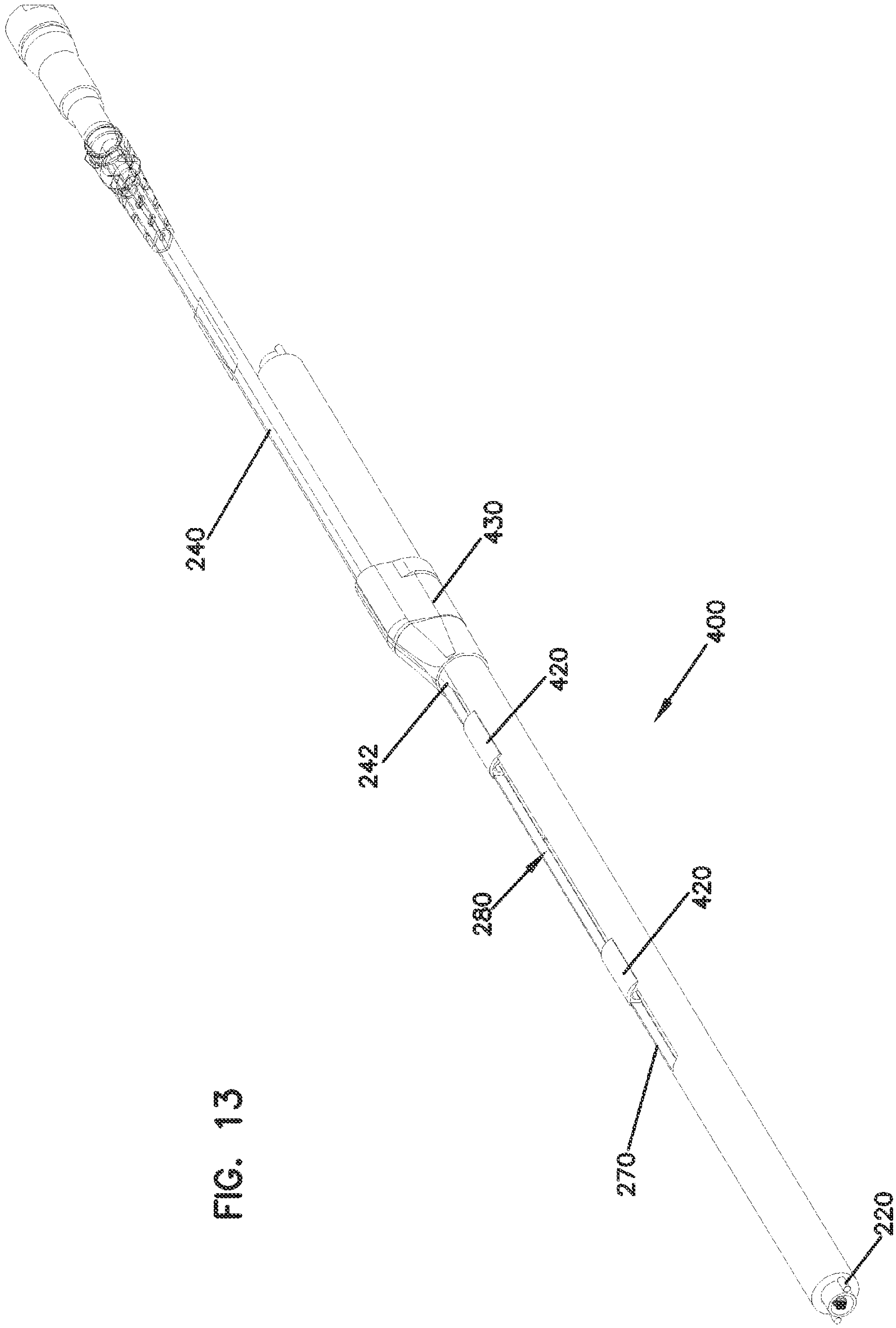
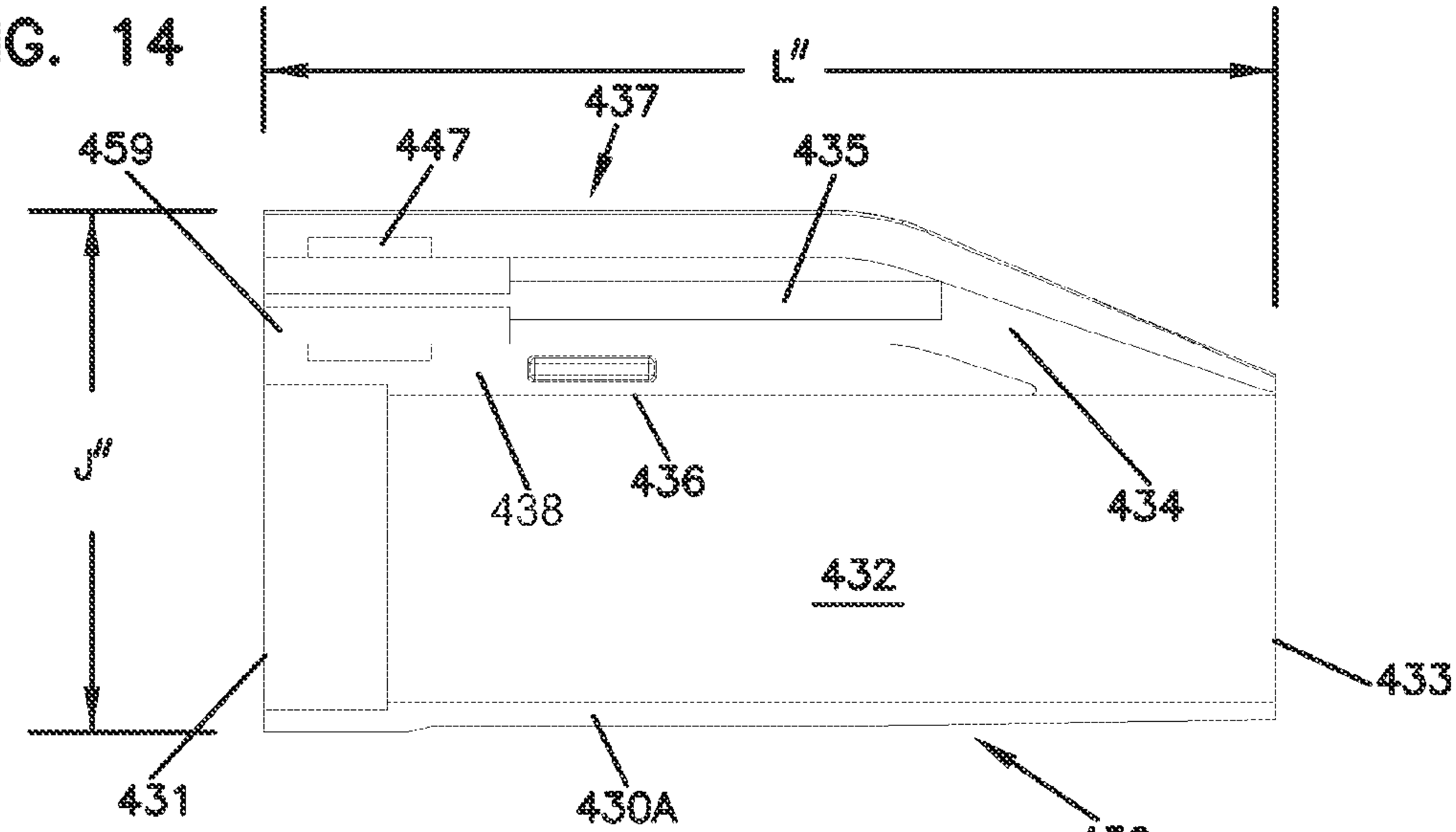


FIG. 13

FIG. 14



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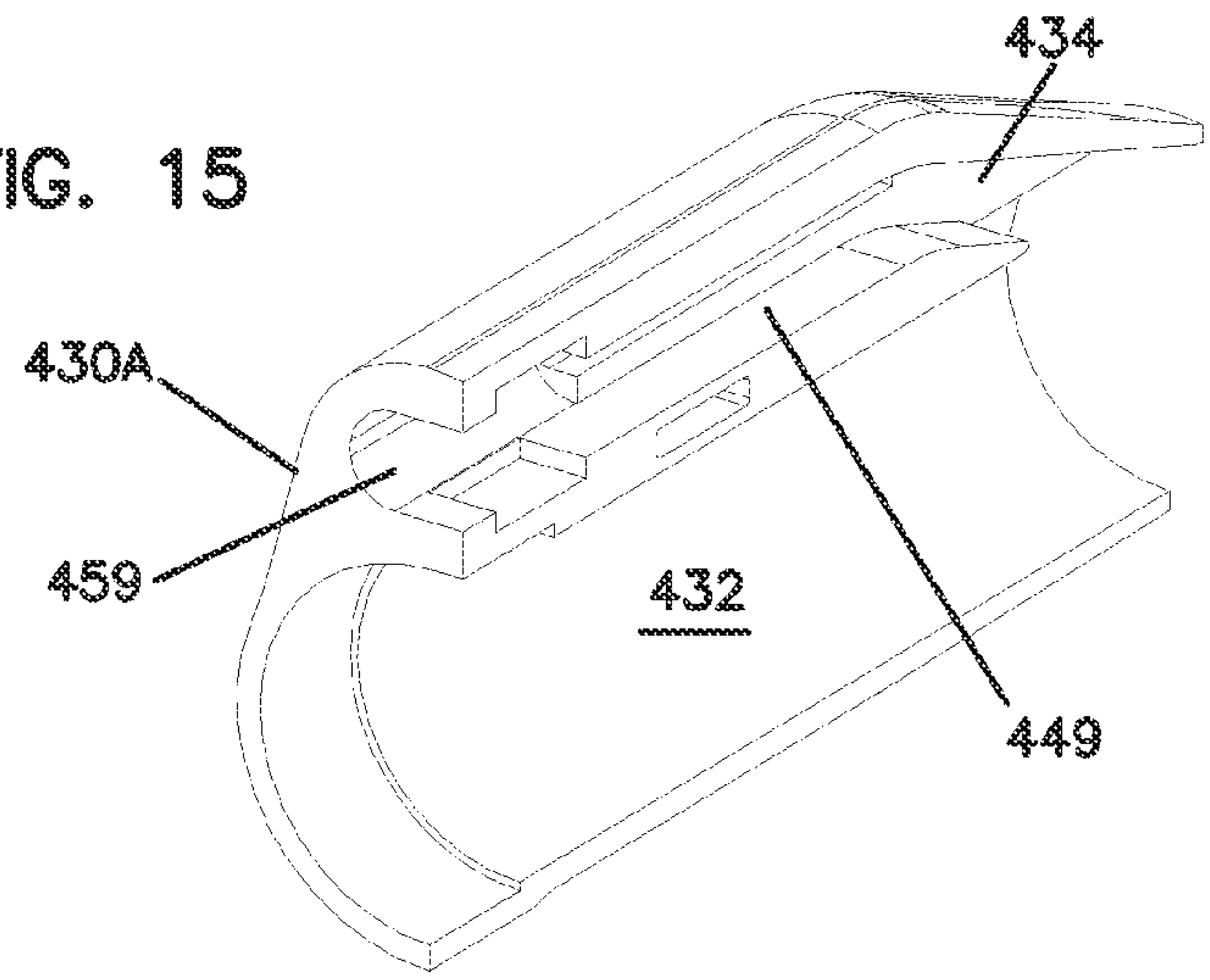

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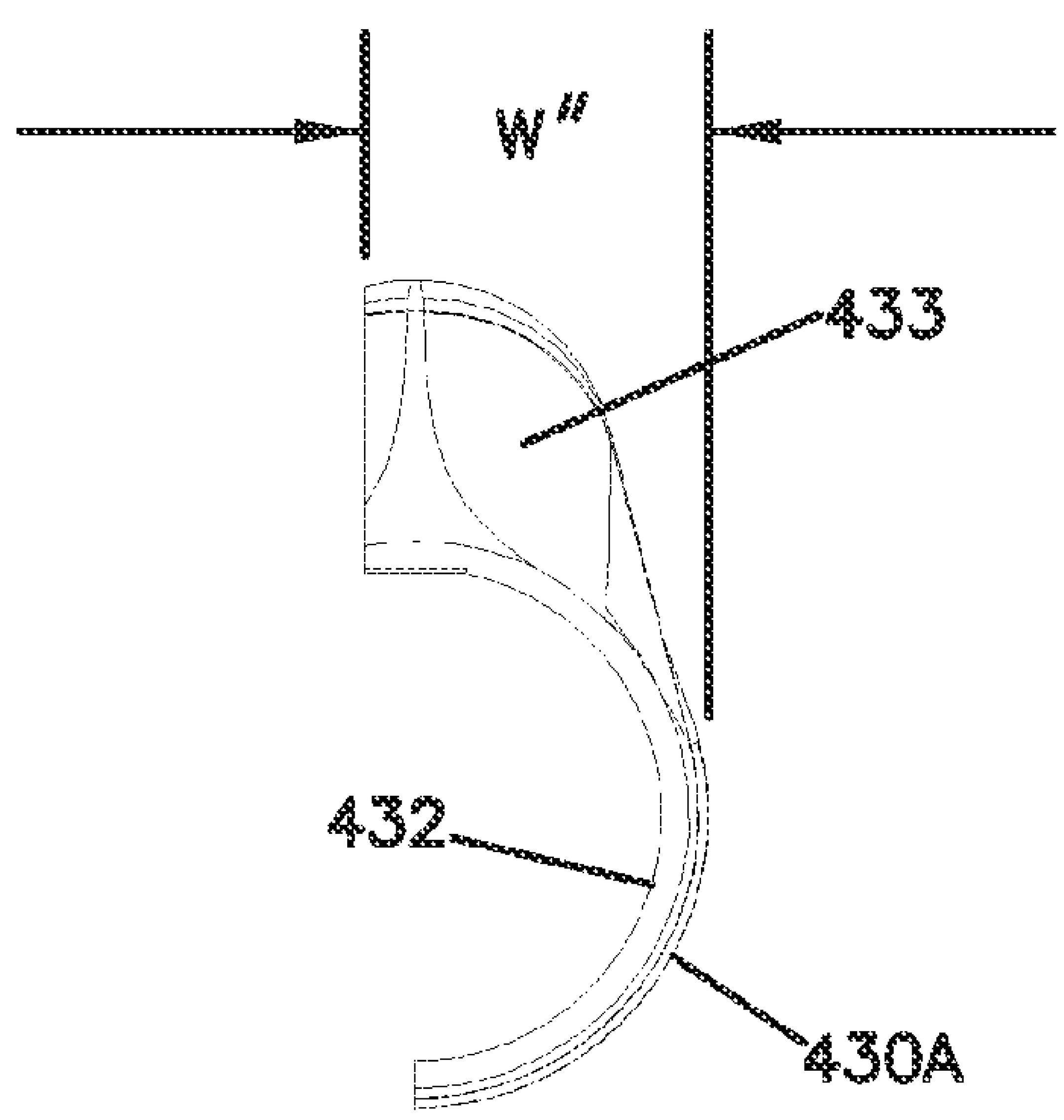

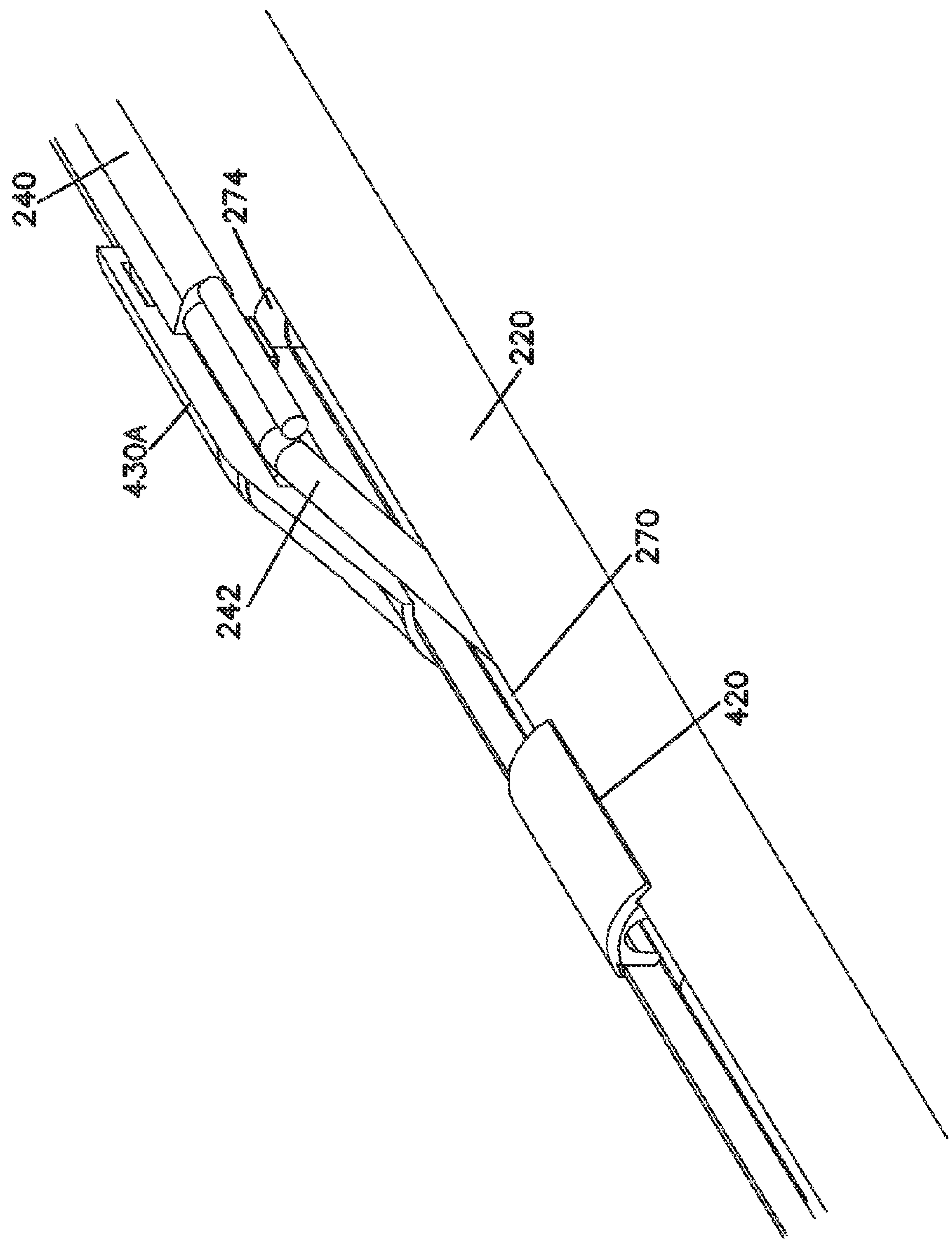

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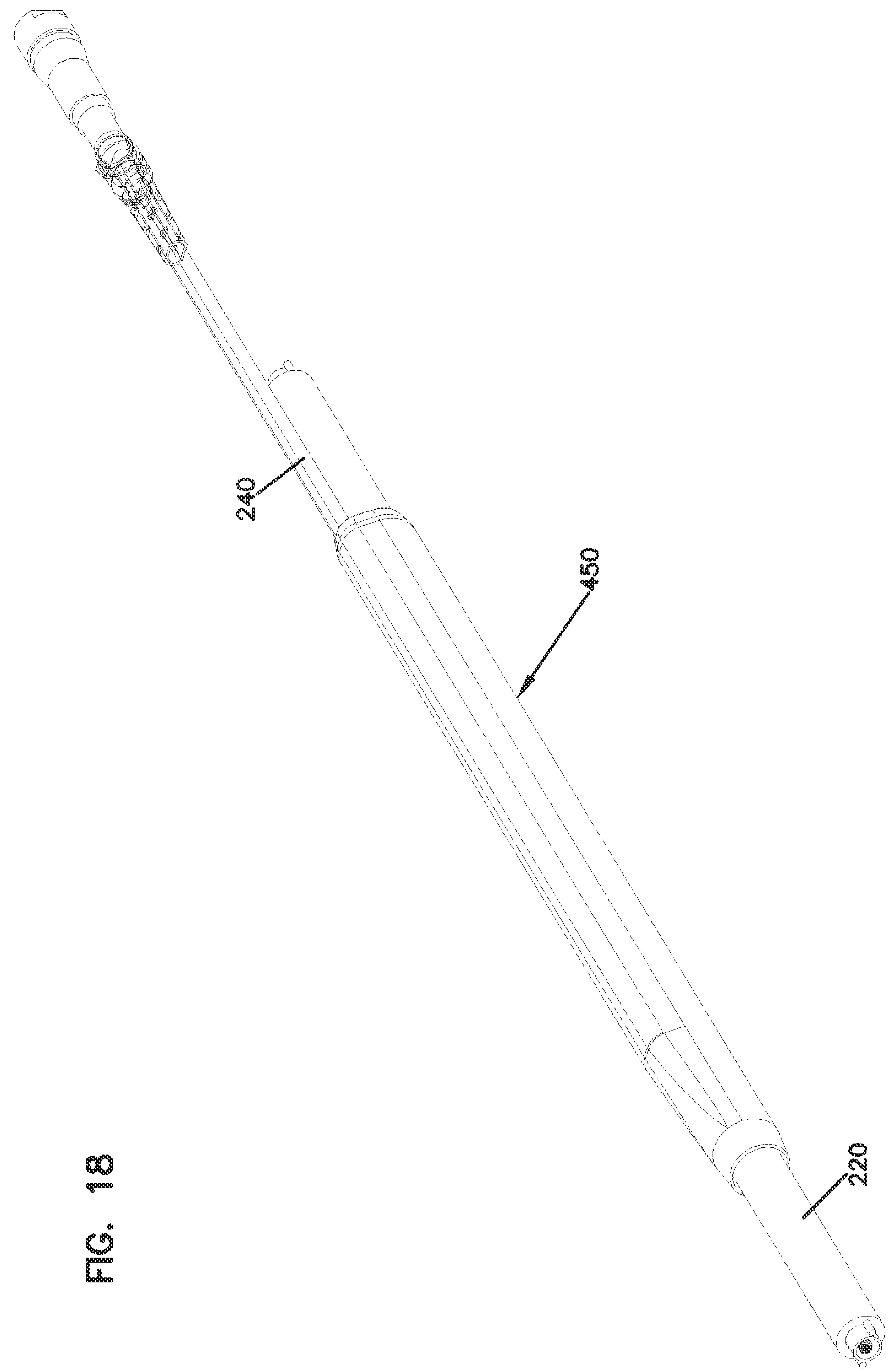

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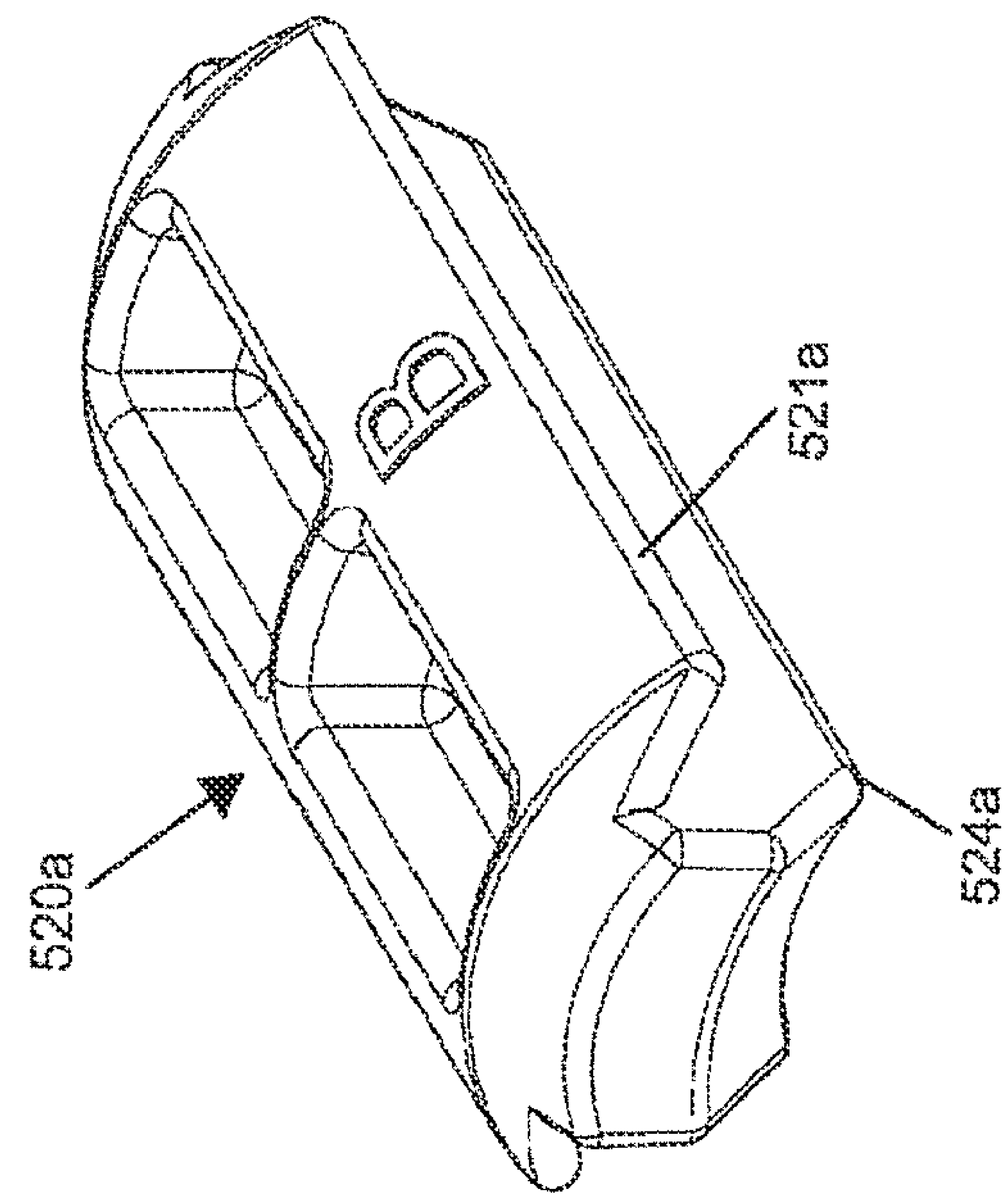


FIG.19

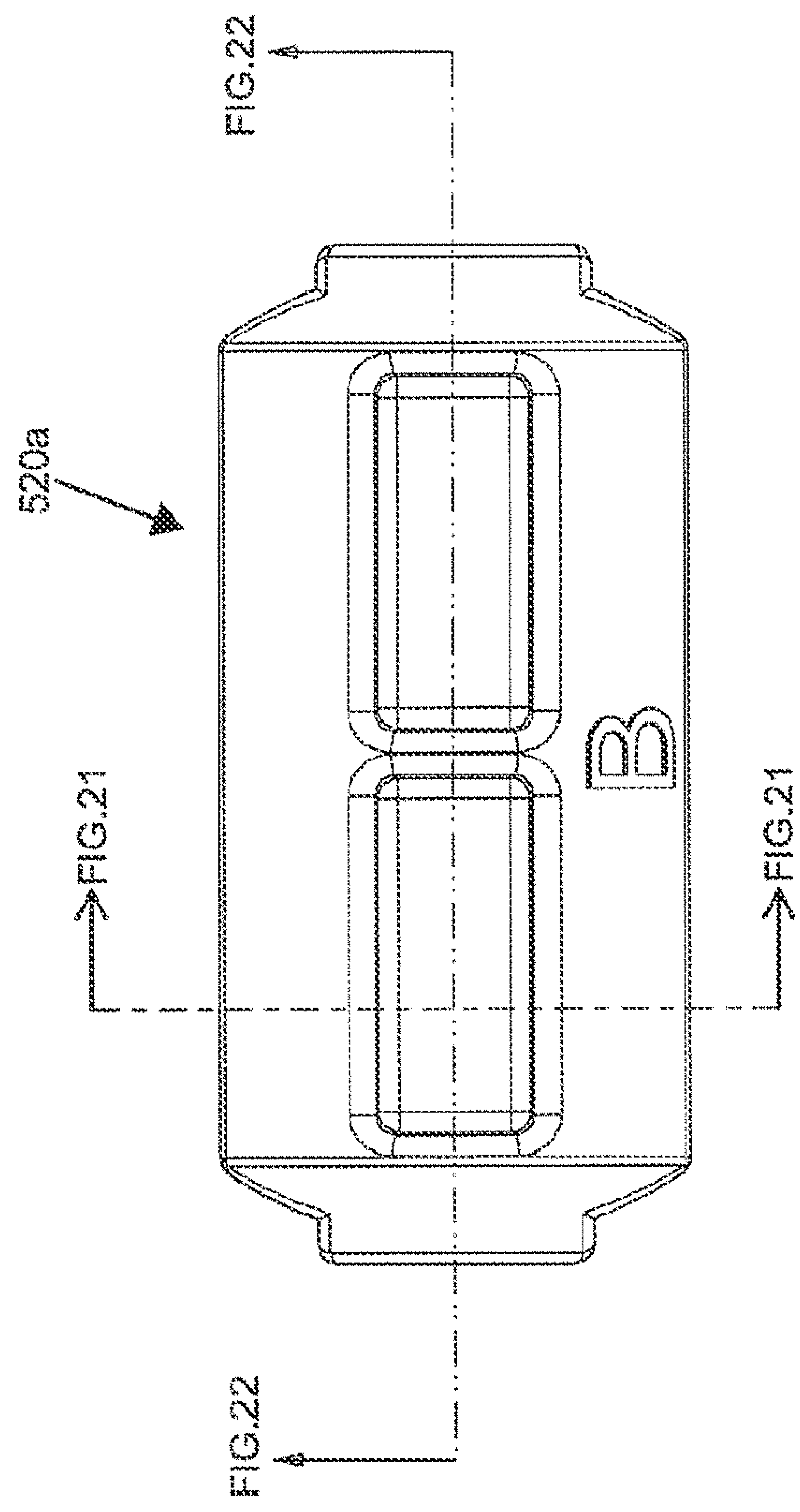
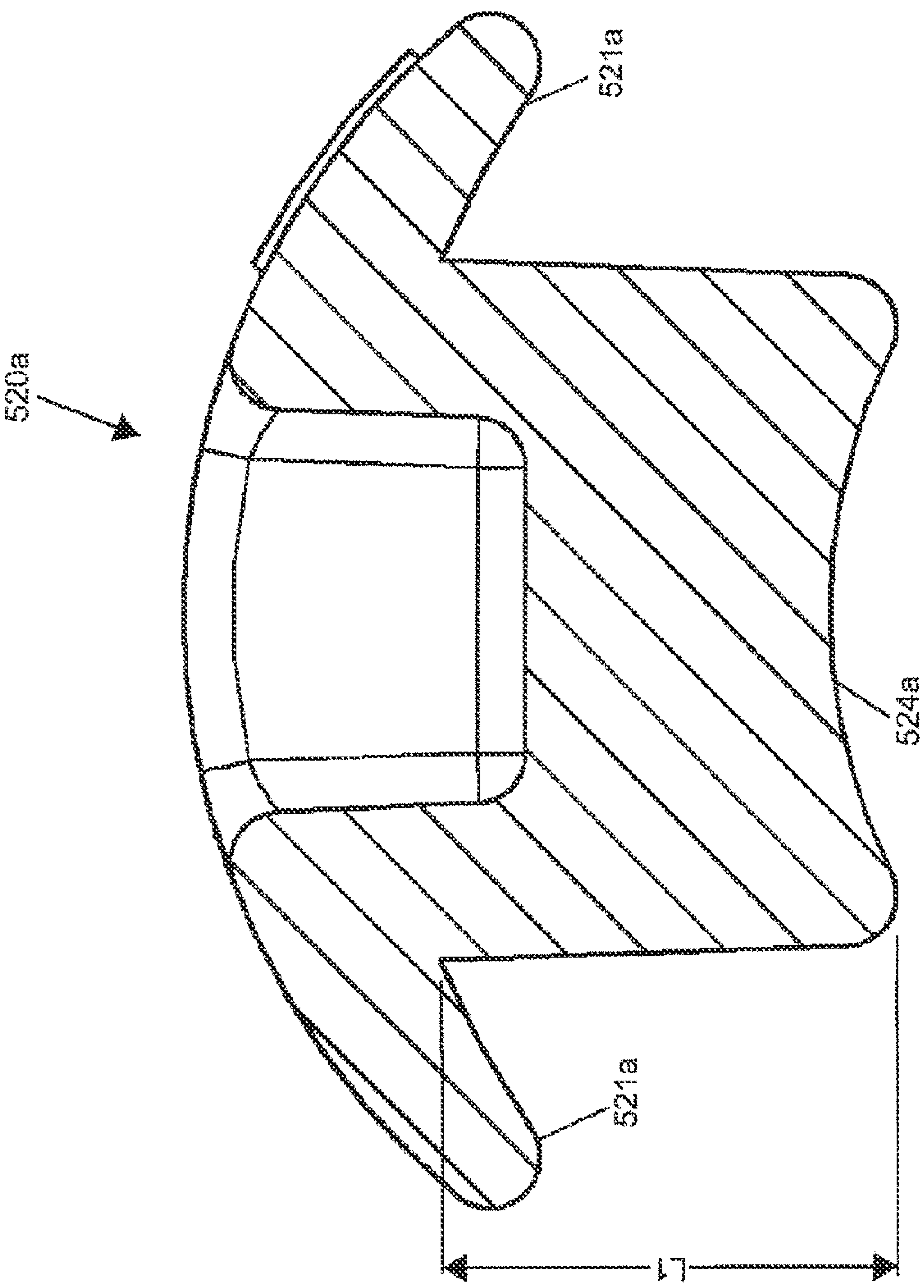


FIG.20



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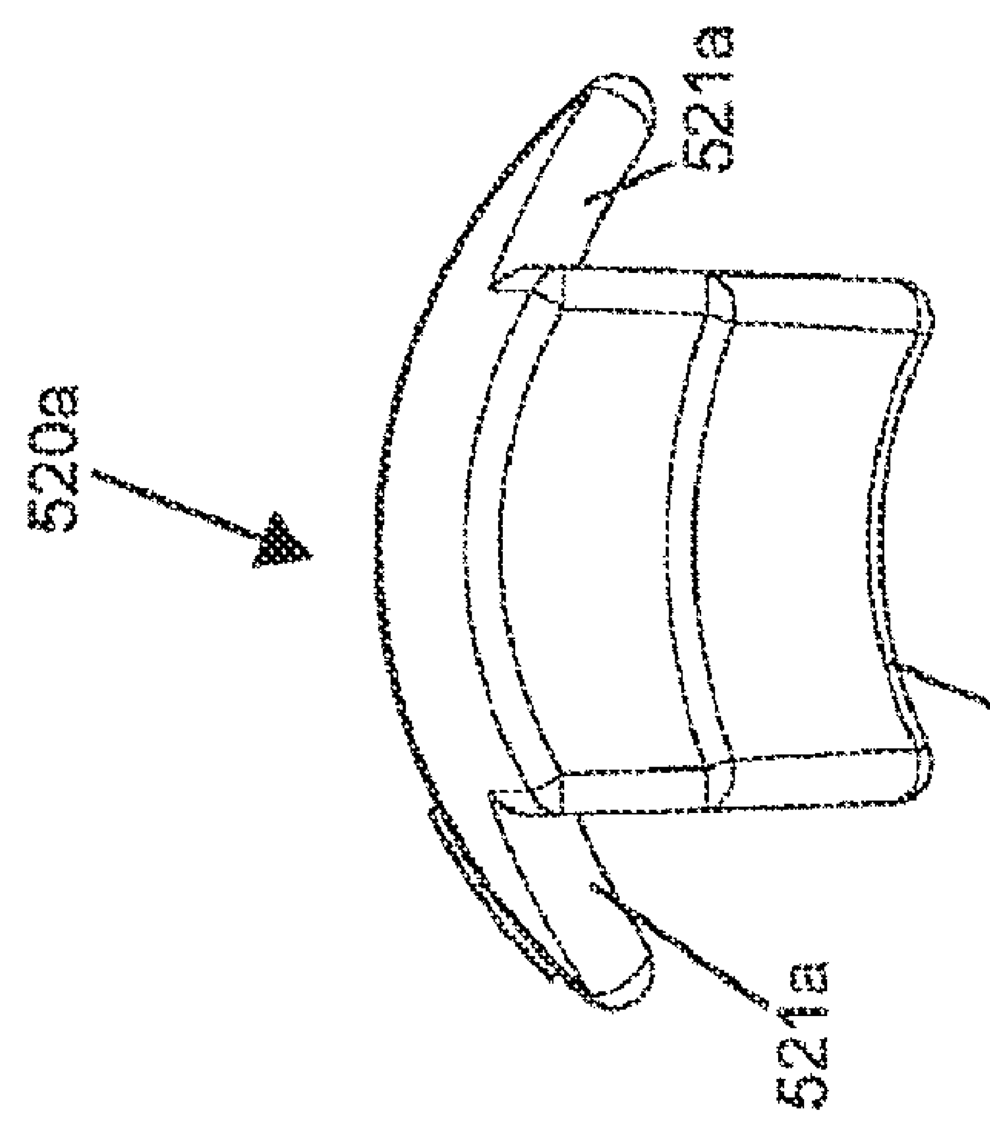
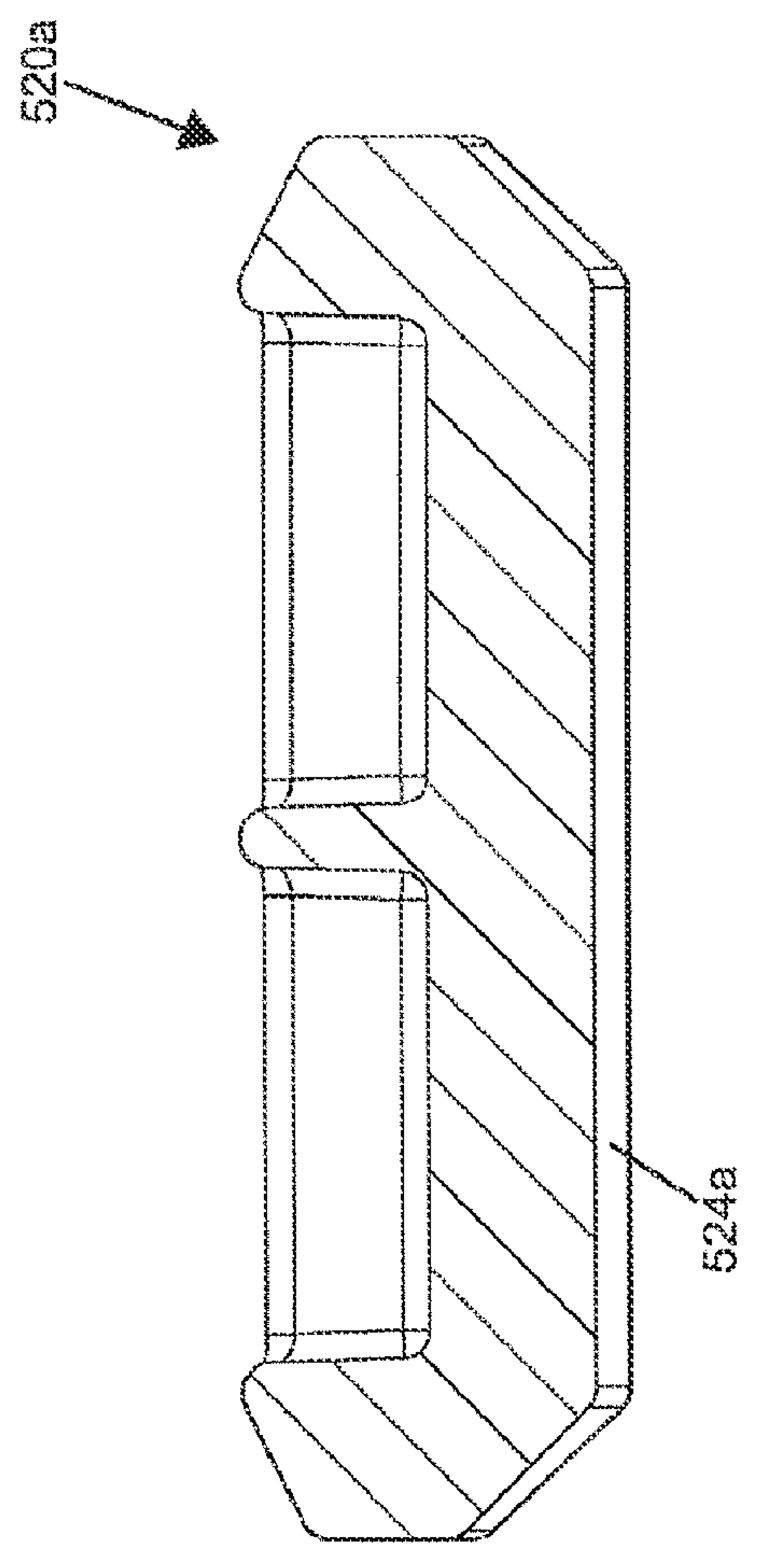


FIG.23



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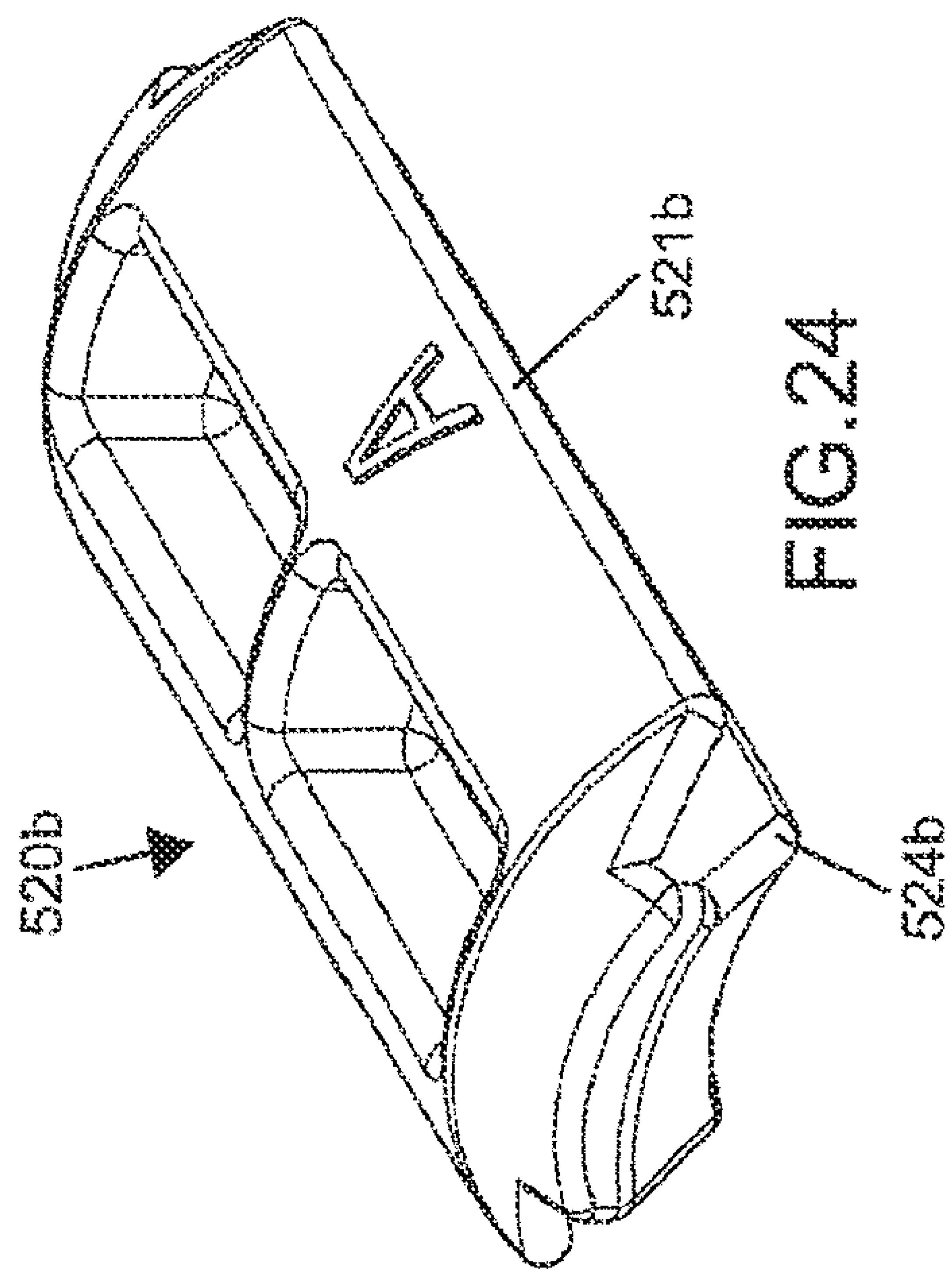

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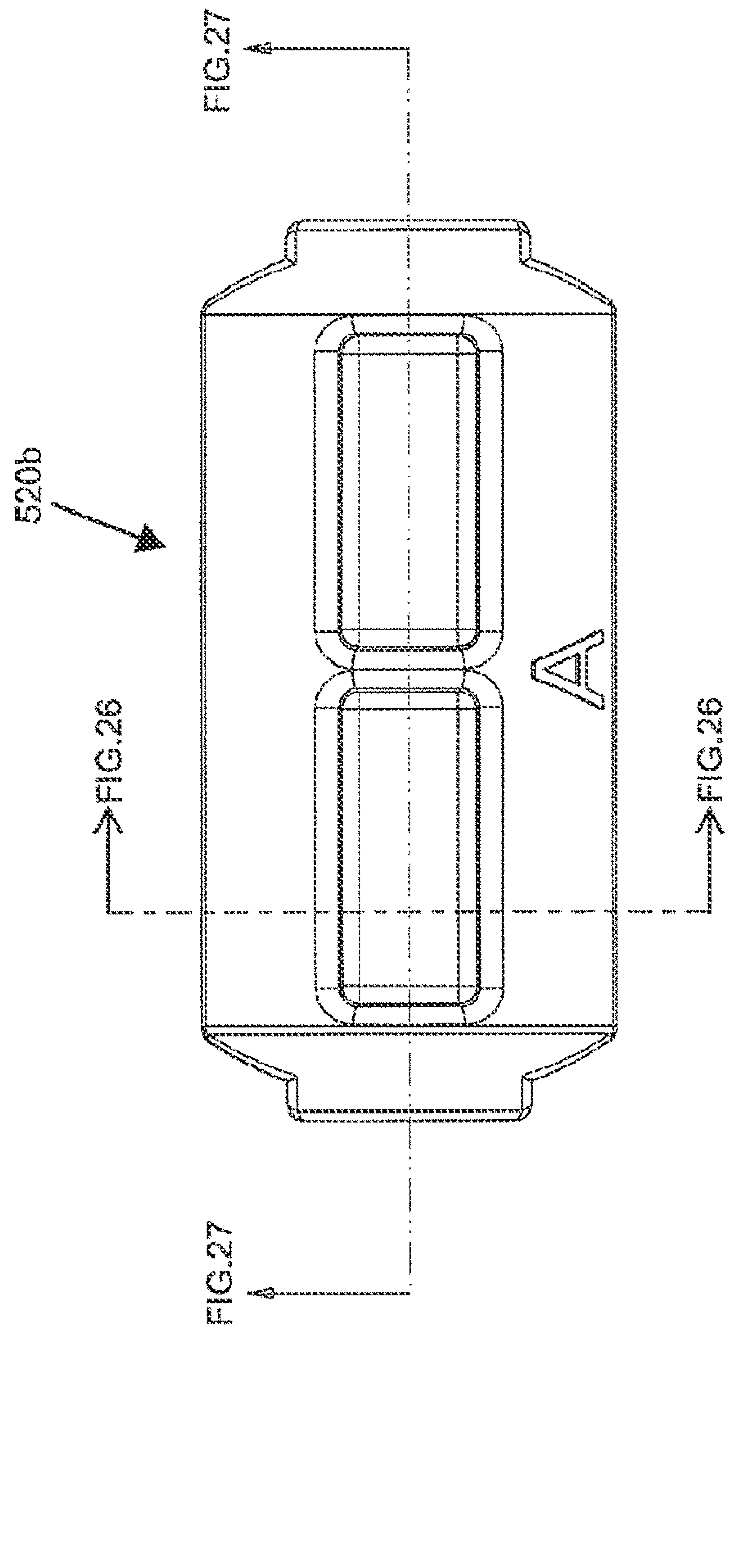

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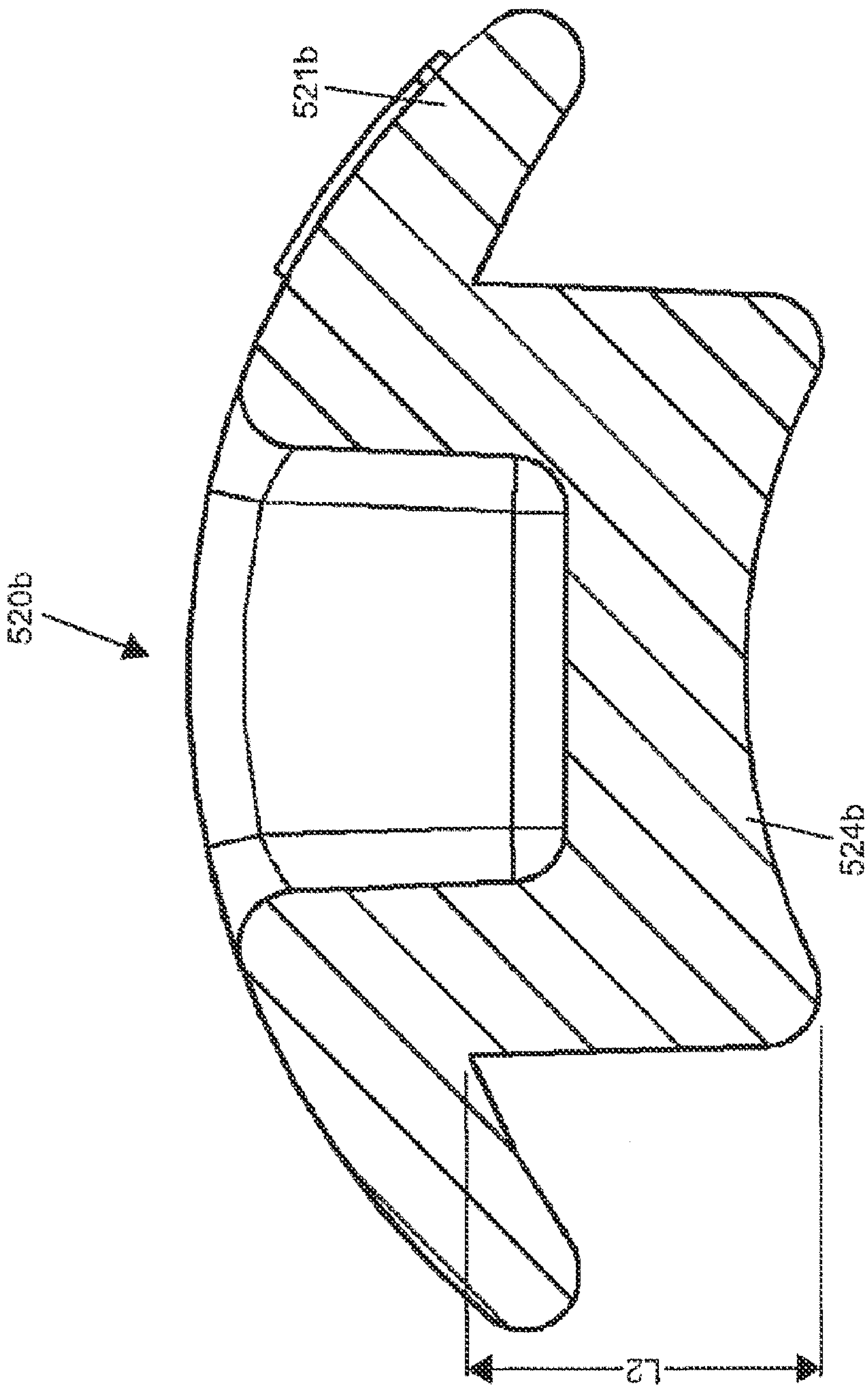
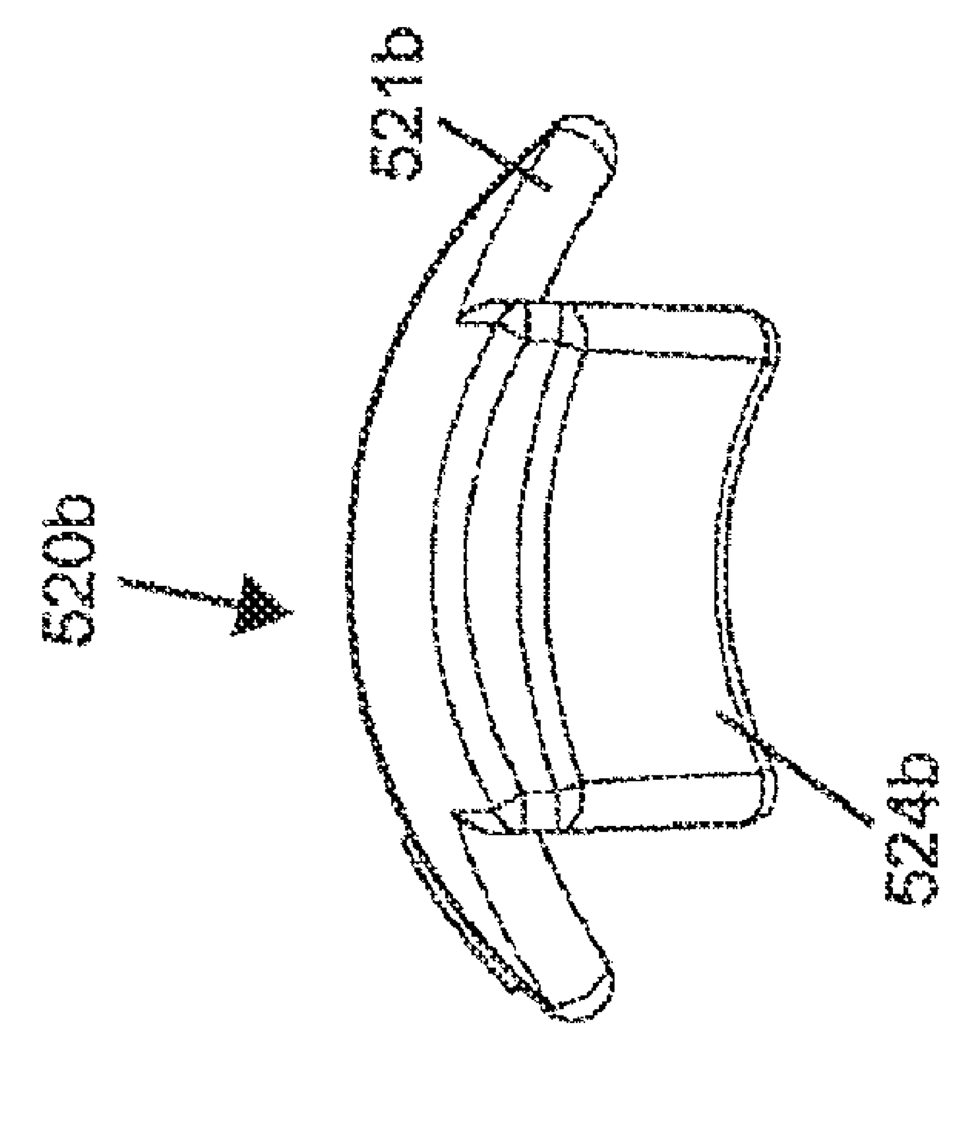


FIG.26



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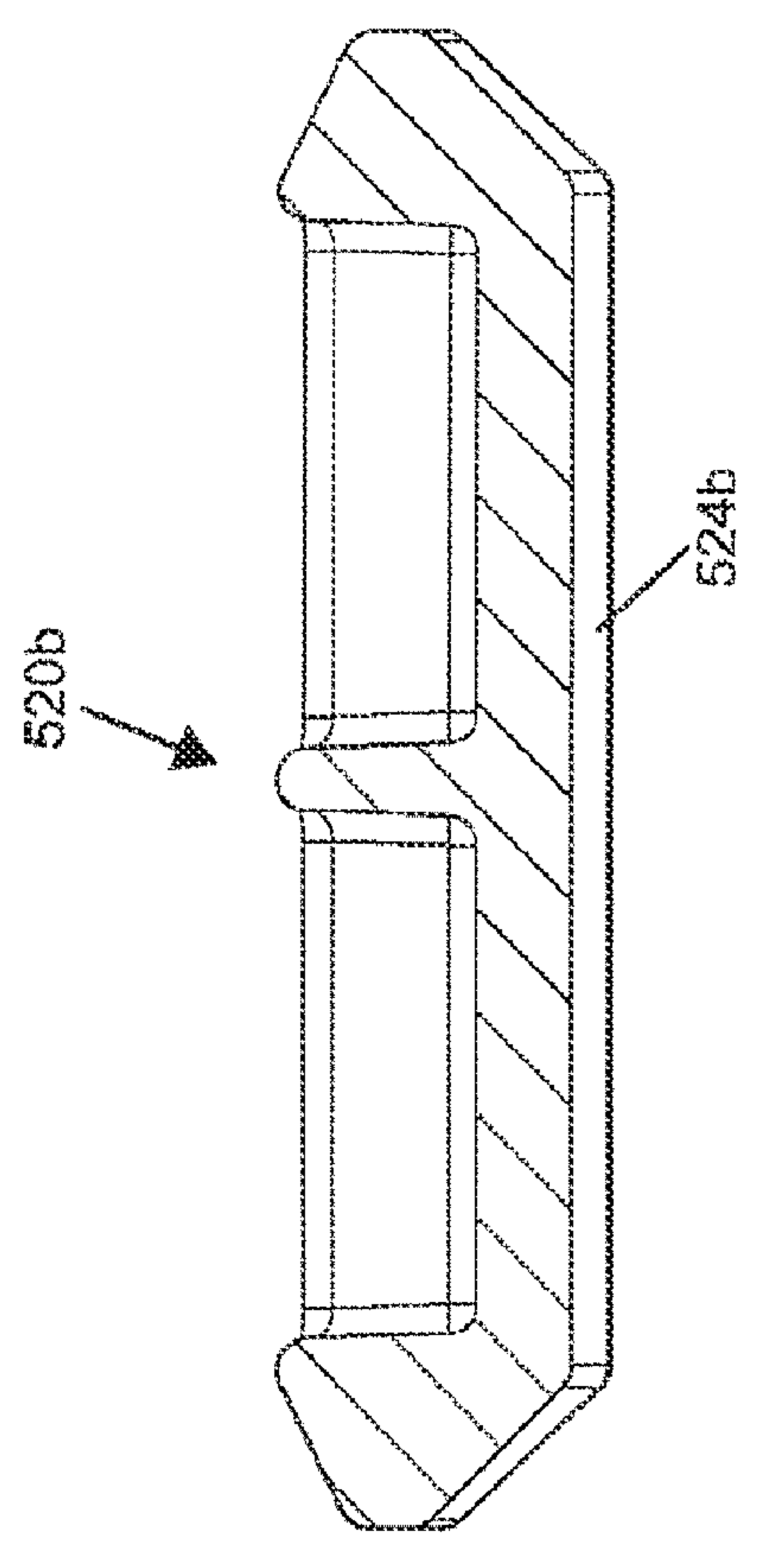


FIG.27

FIG. 29

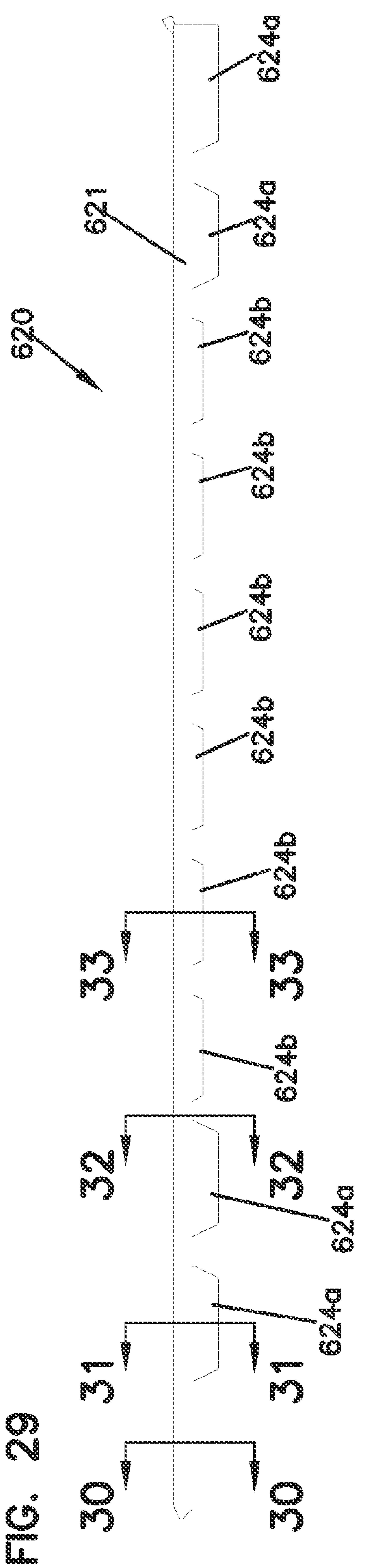


FIG. 30

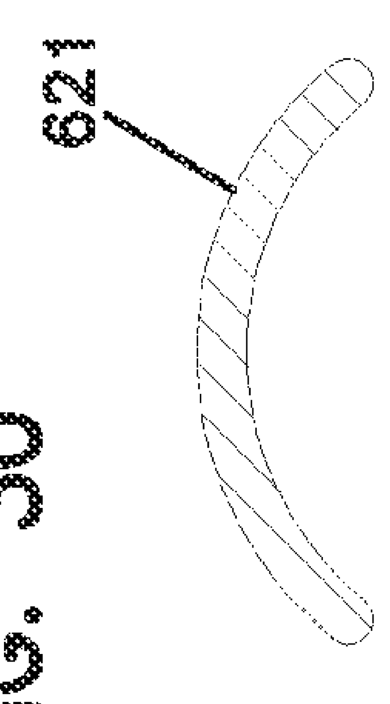


FIG. 31

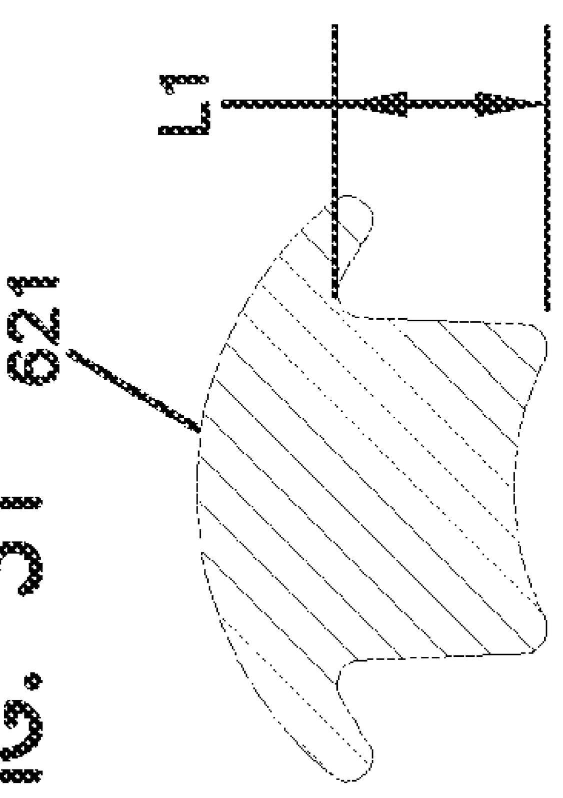


FIG. 32

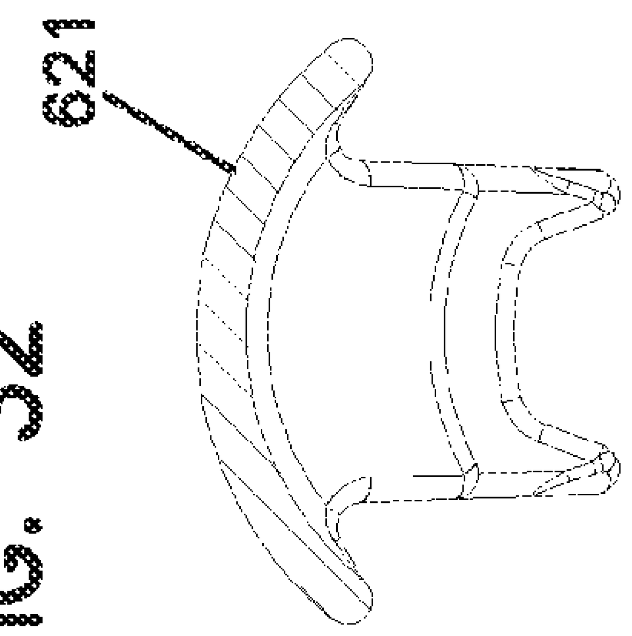


FIG. 33

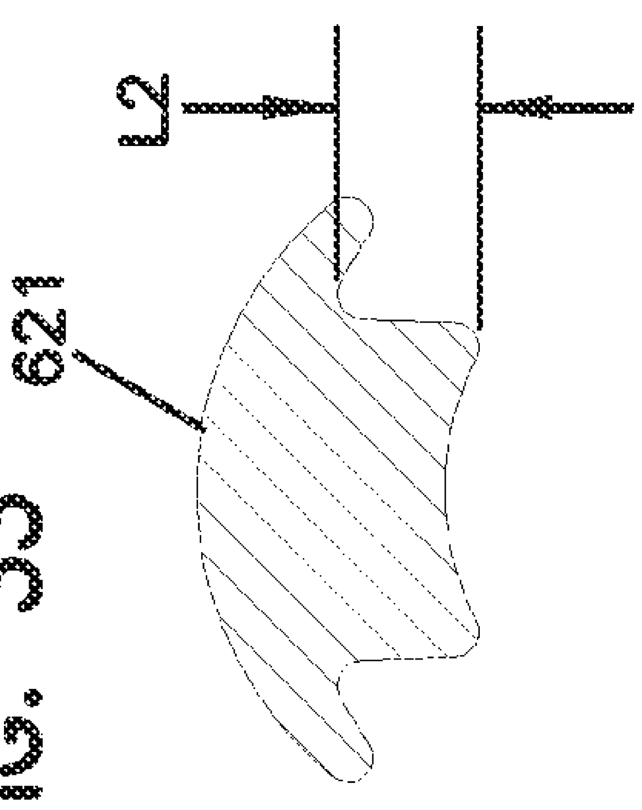


FIG. 34

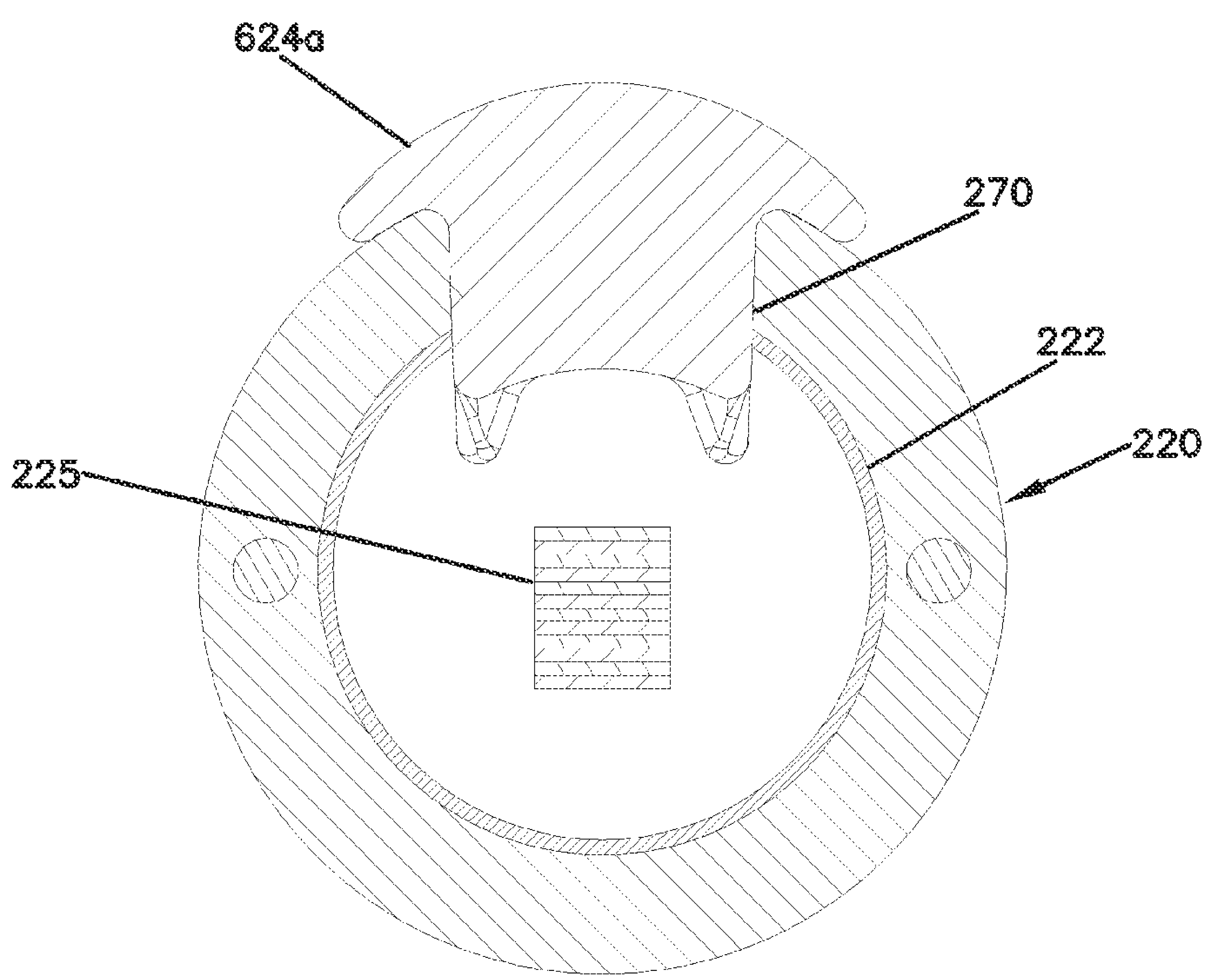
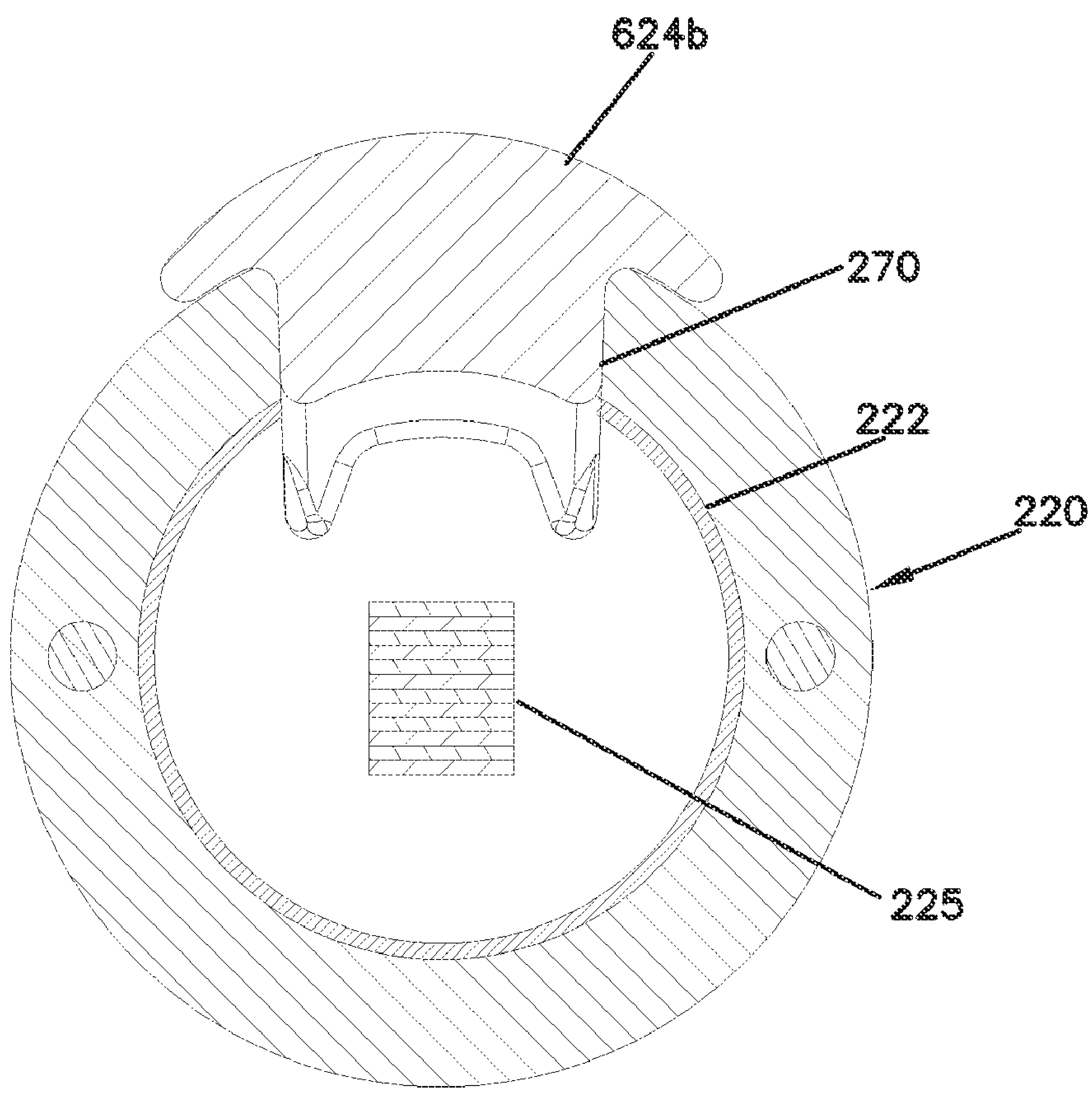


FIG. 35



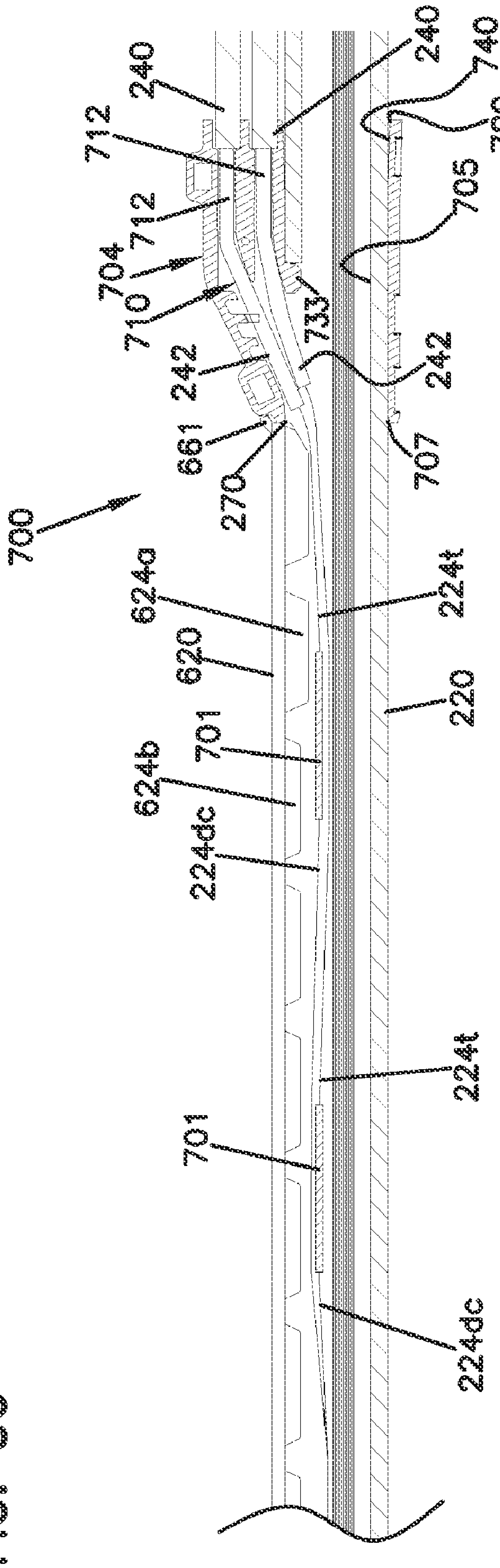
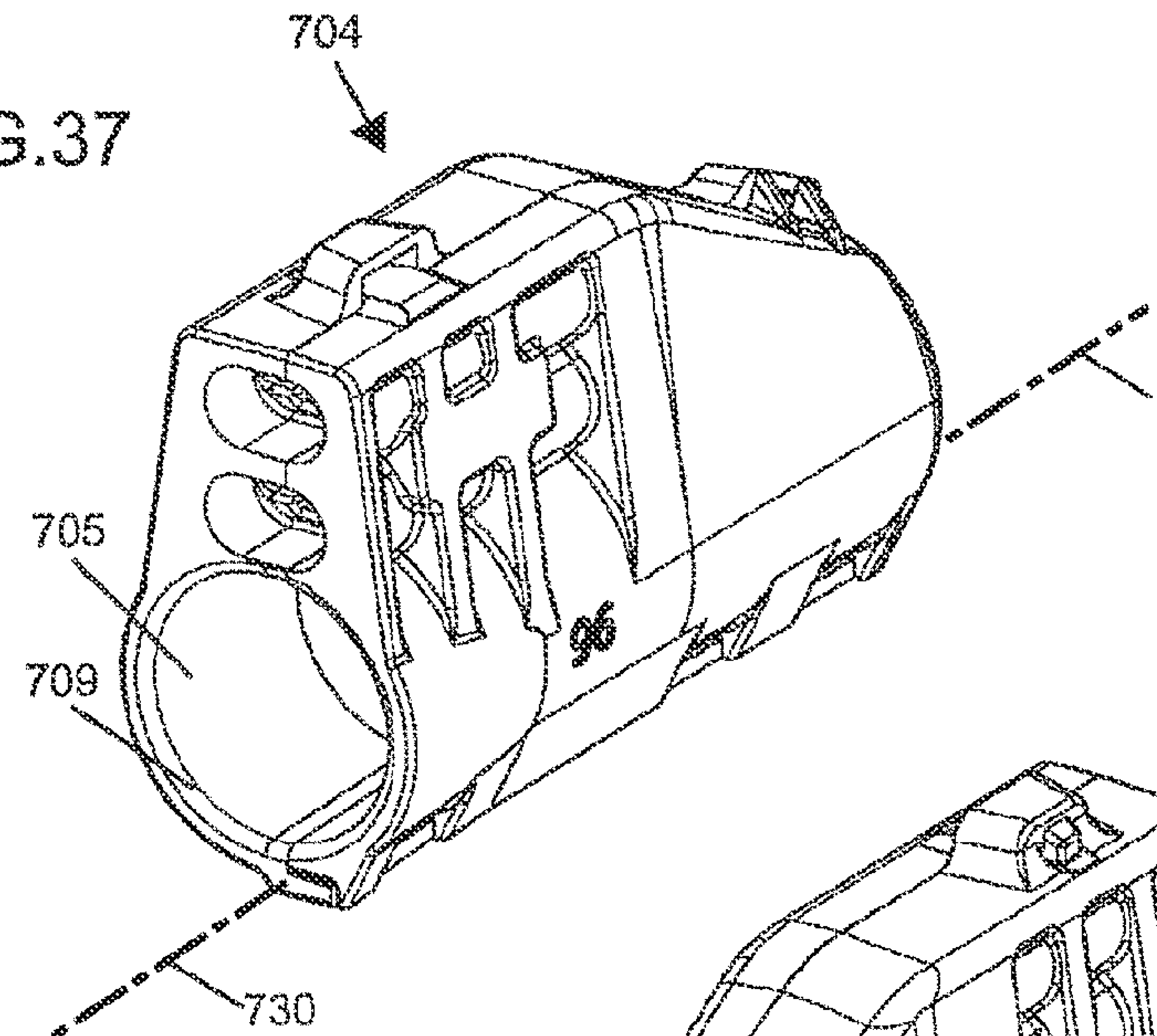

240
240
740
709
712
712
705
704
710
733
242
242
661
707
270
700
624a
224t
620
220
701
624b
224dc
224t
701
224dc

FIG. 36

FIG.37



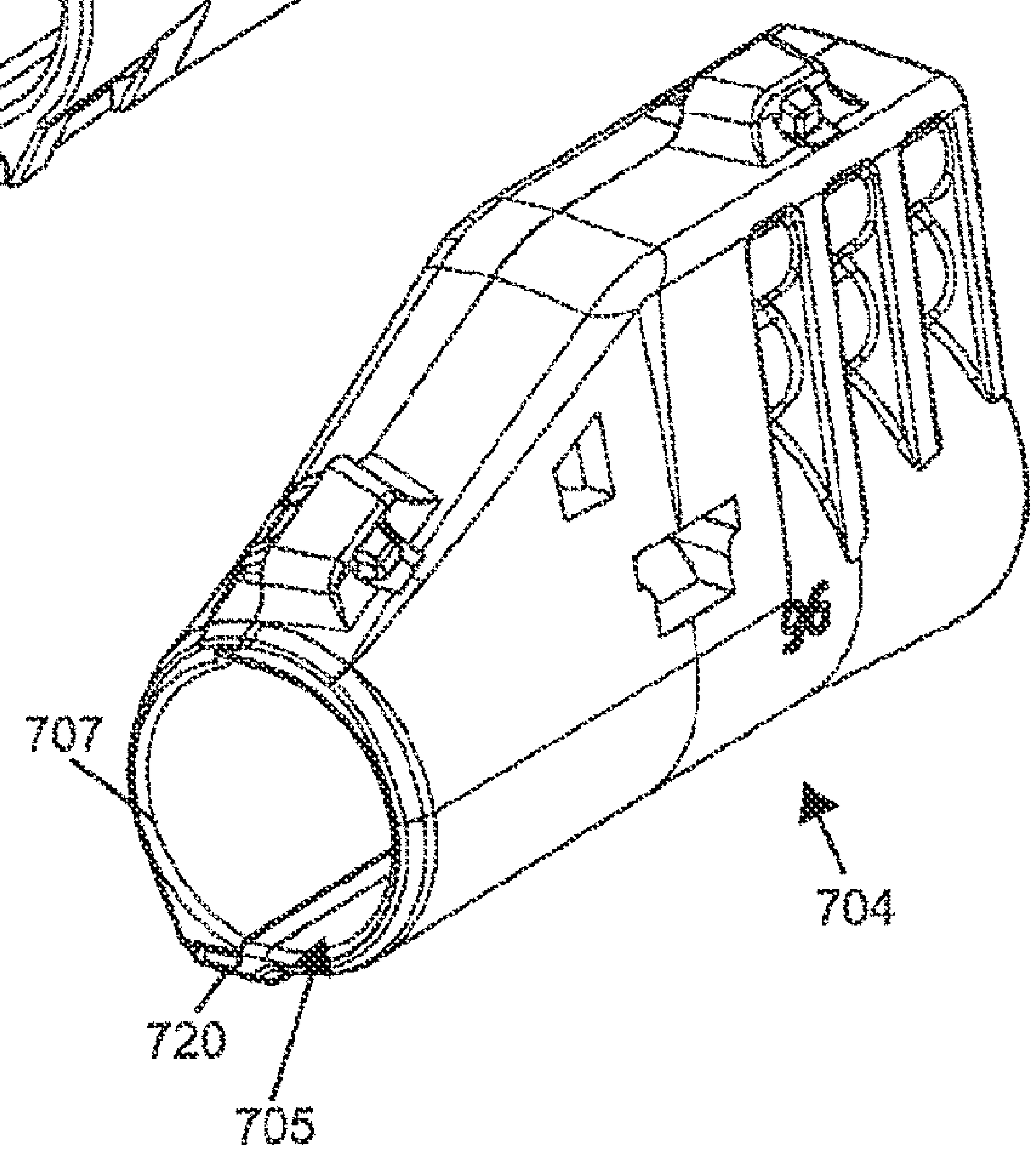


FIG.38

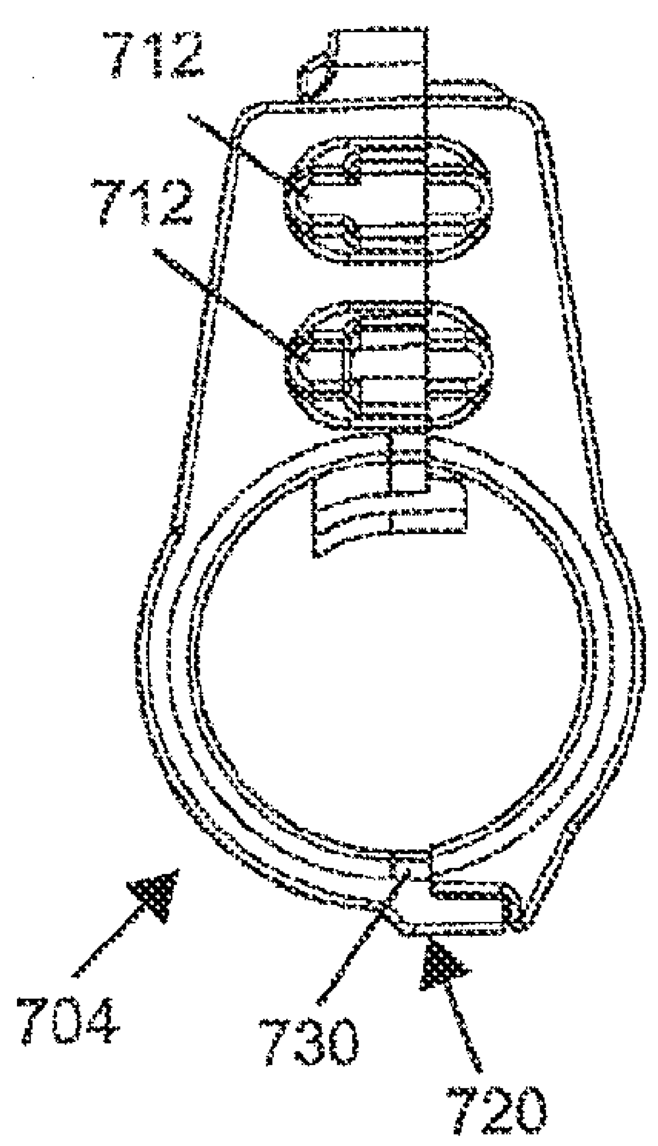


FIG.43

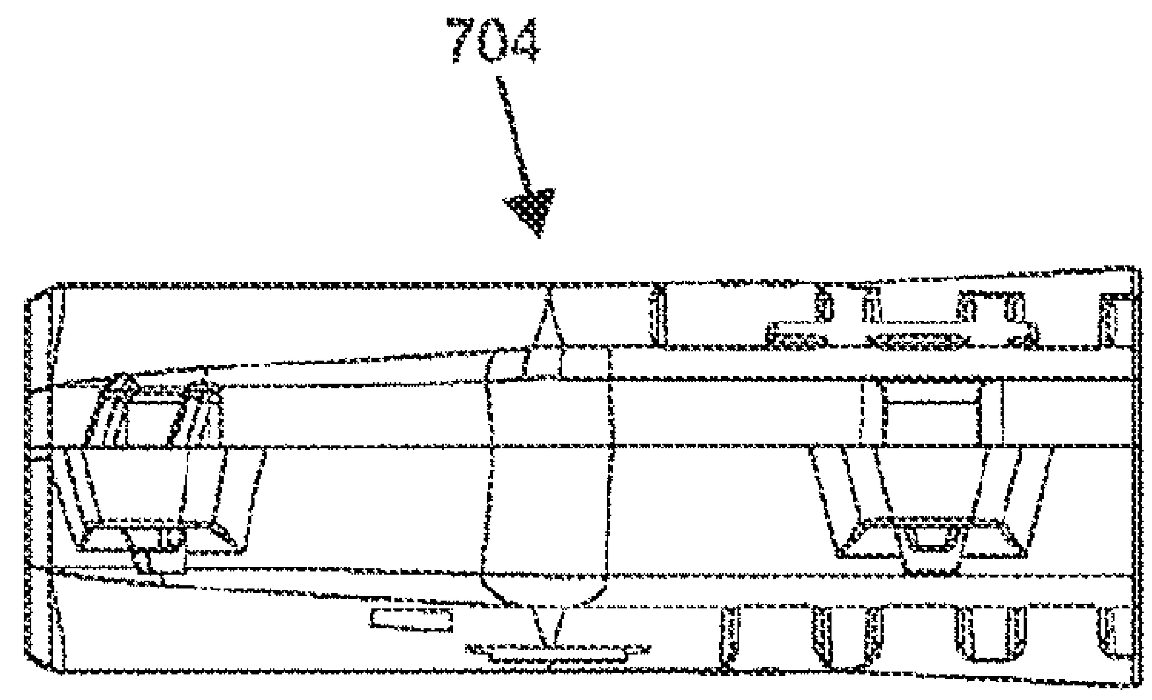


FIG.40

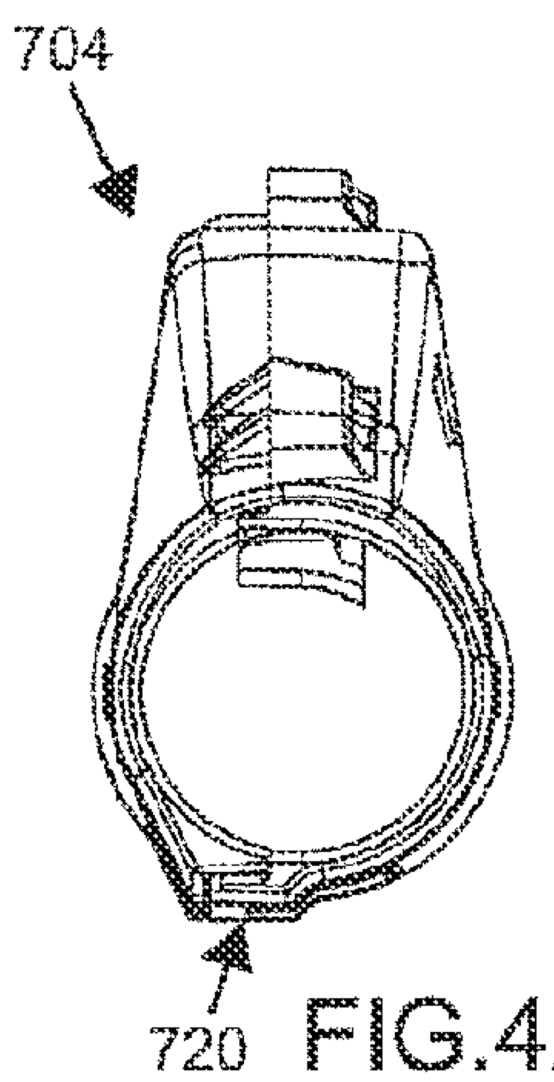


FIG.42

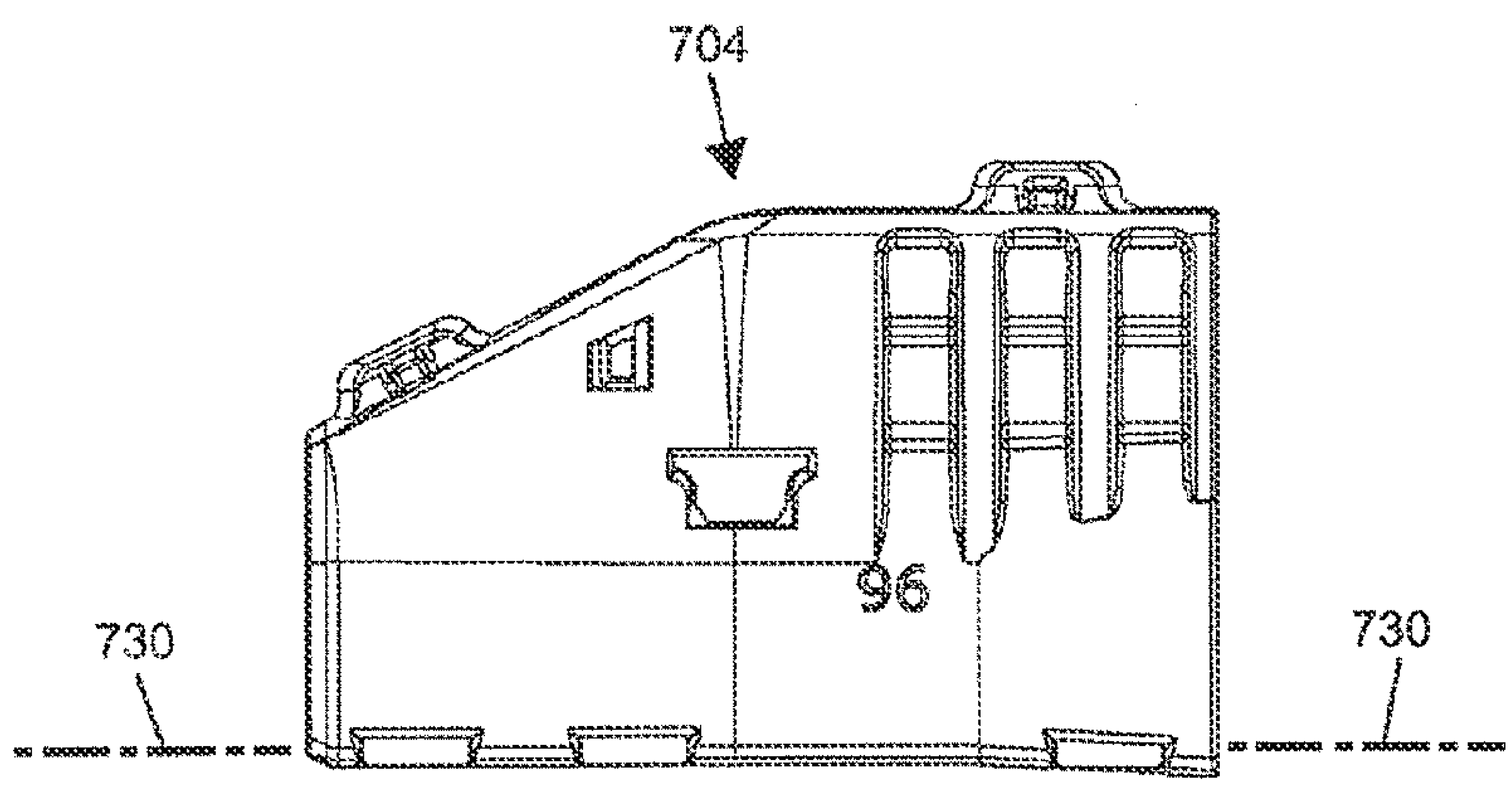


FIG.39

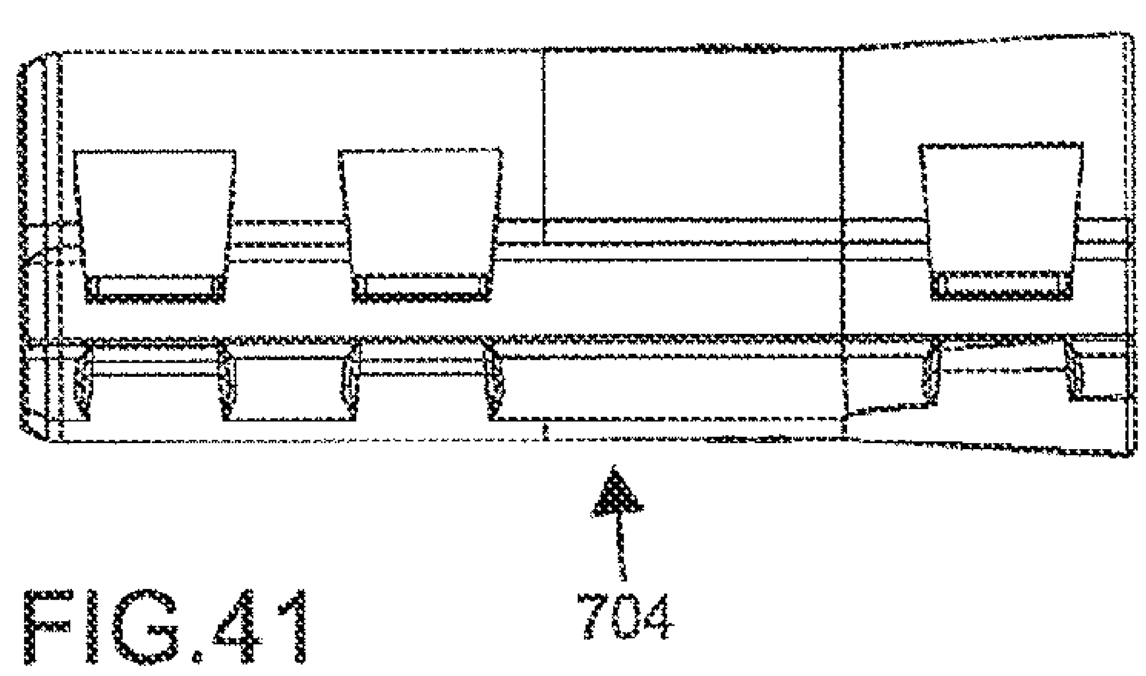


FIG.41

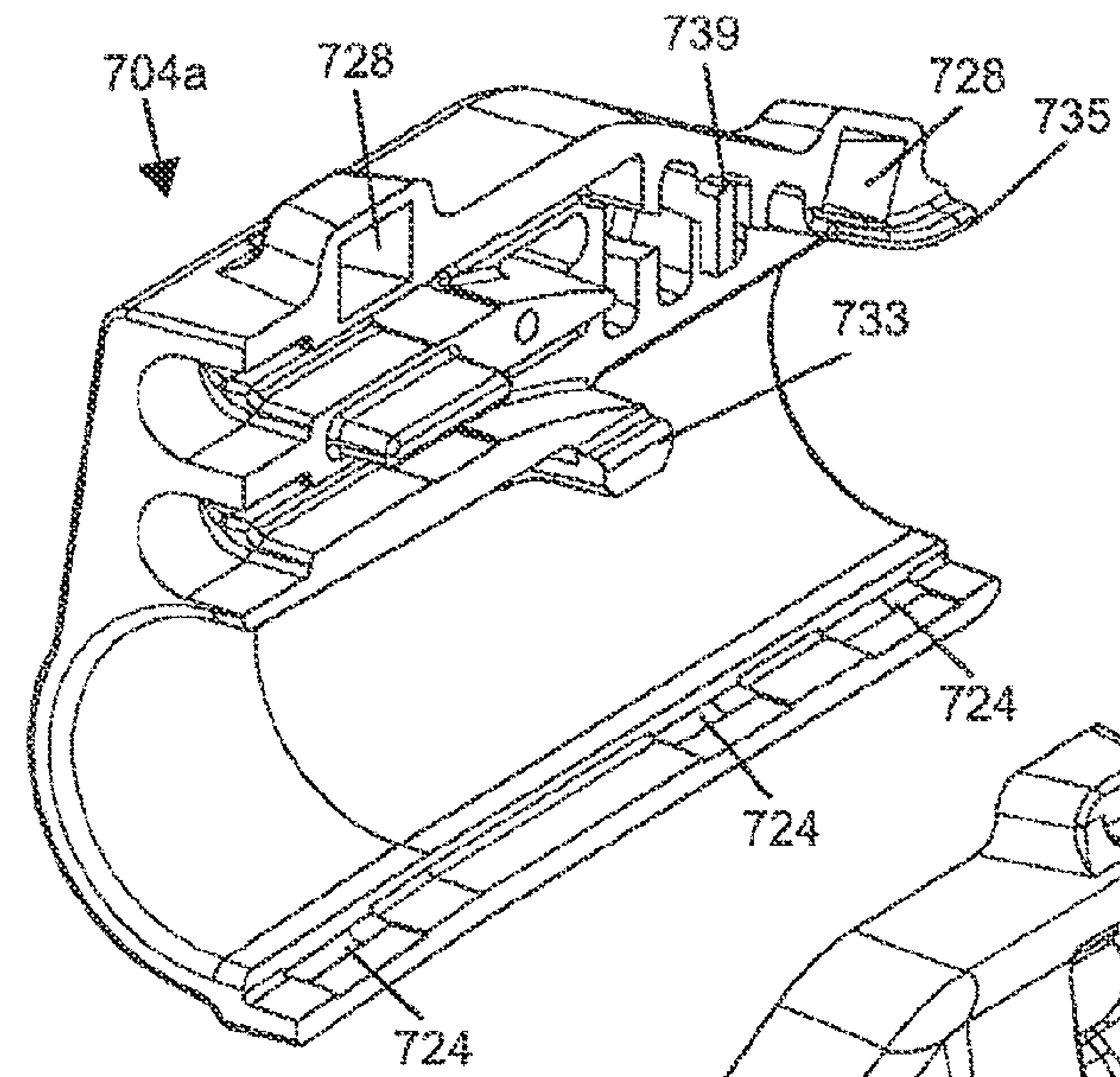


FIG.44

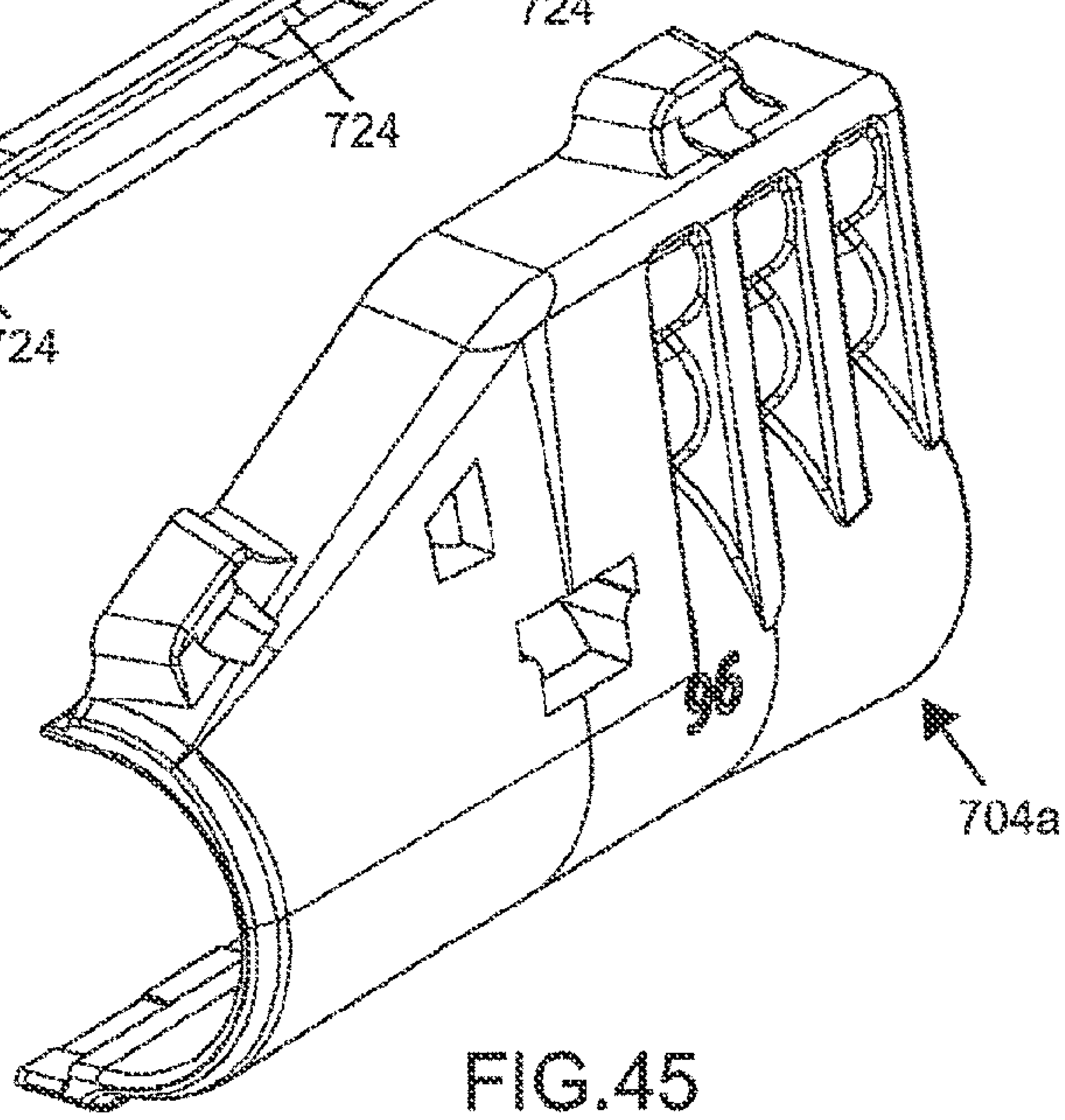
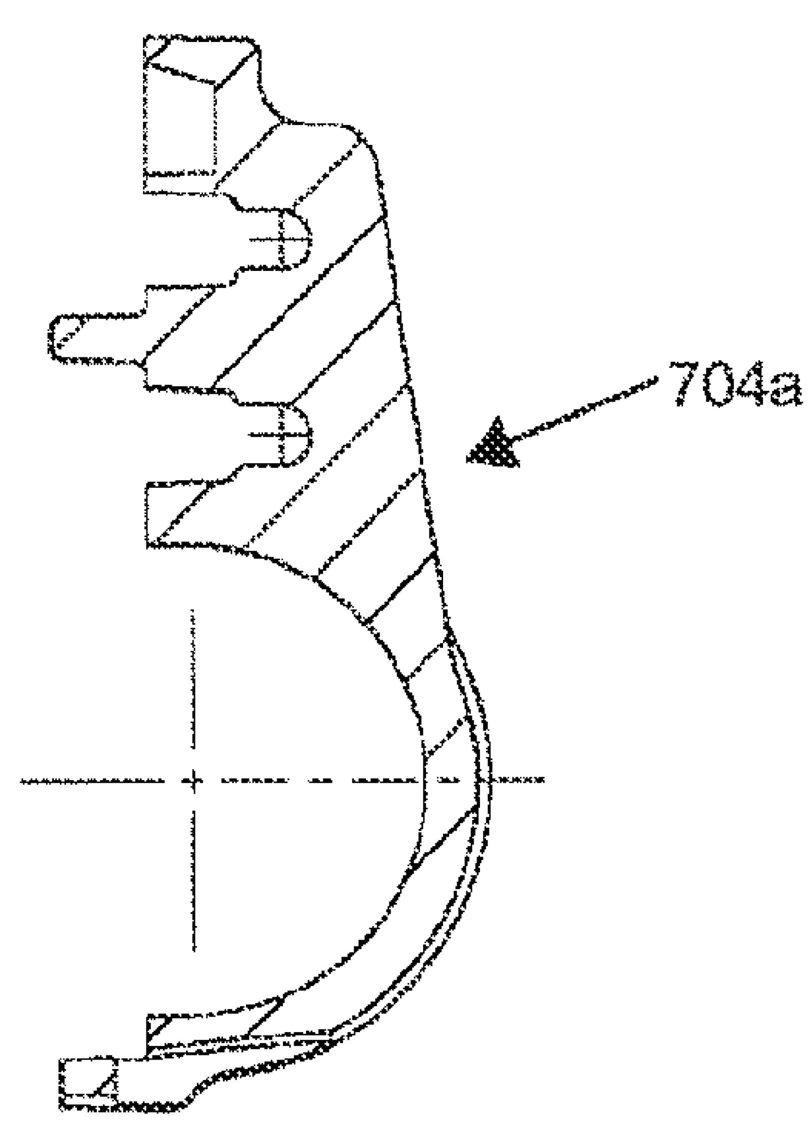


FIG.45

FIG.51



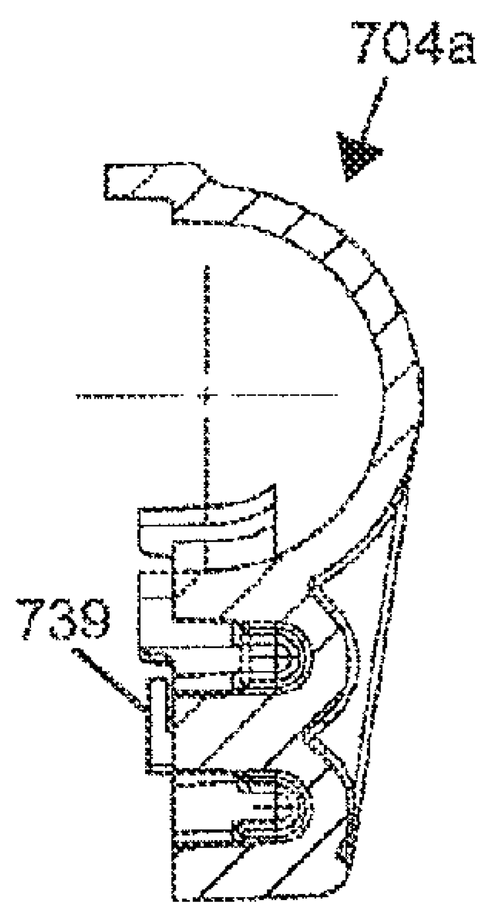


FIG.50

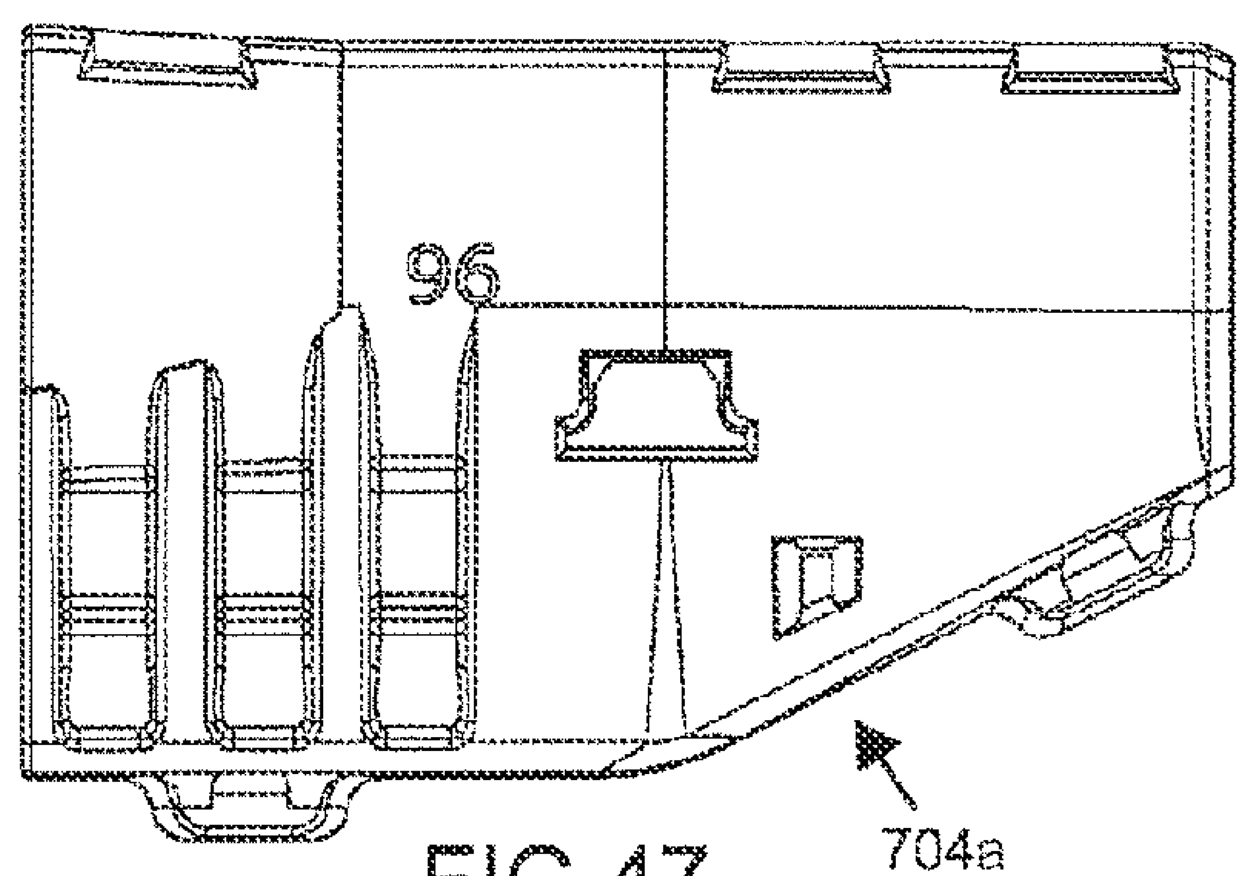


FIG.47

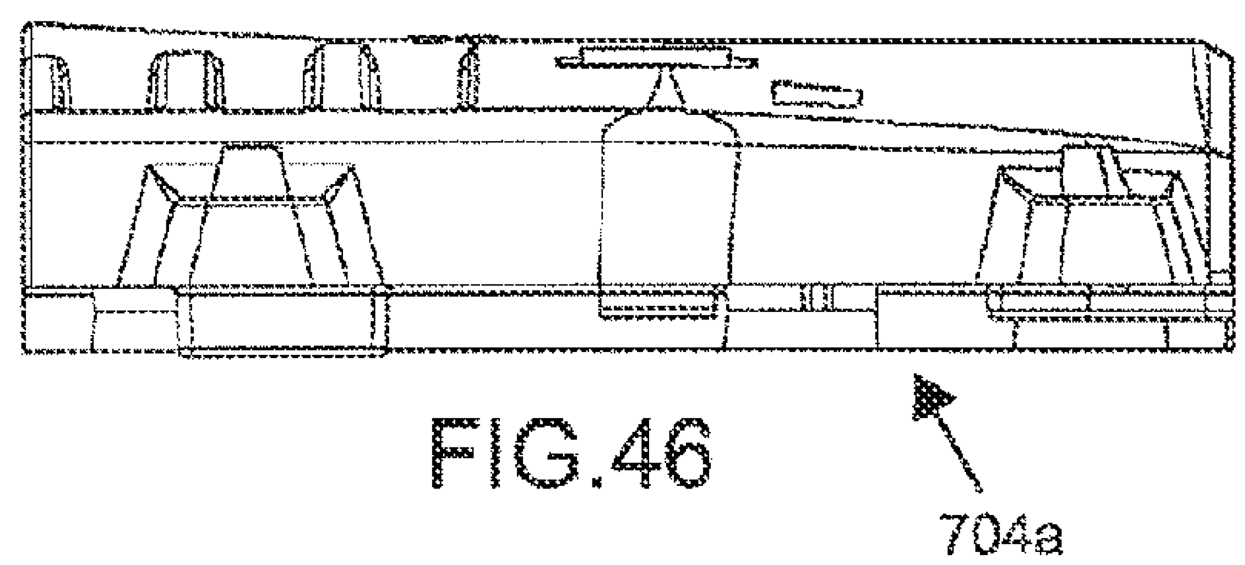


FIG.46

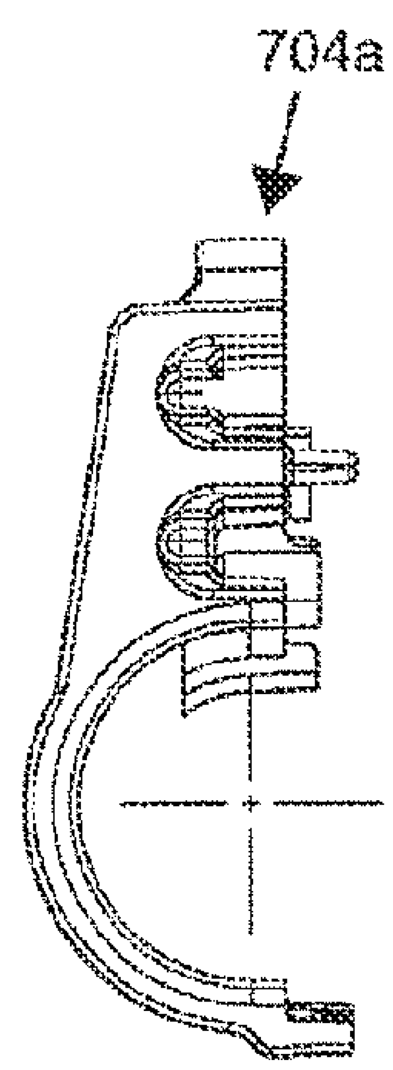


FIG.49

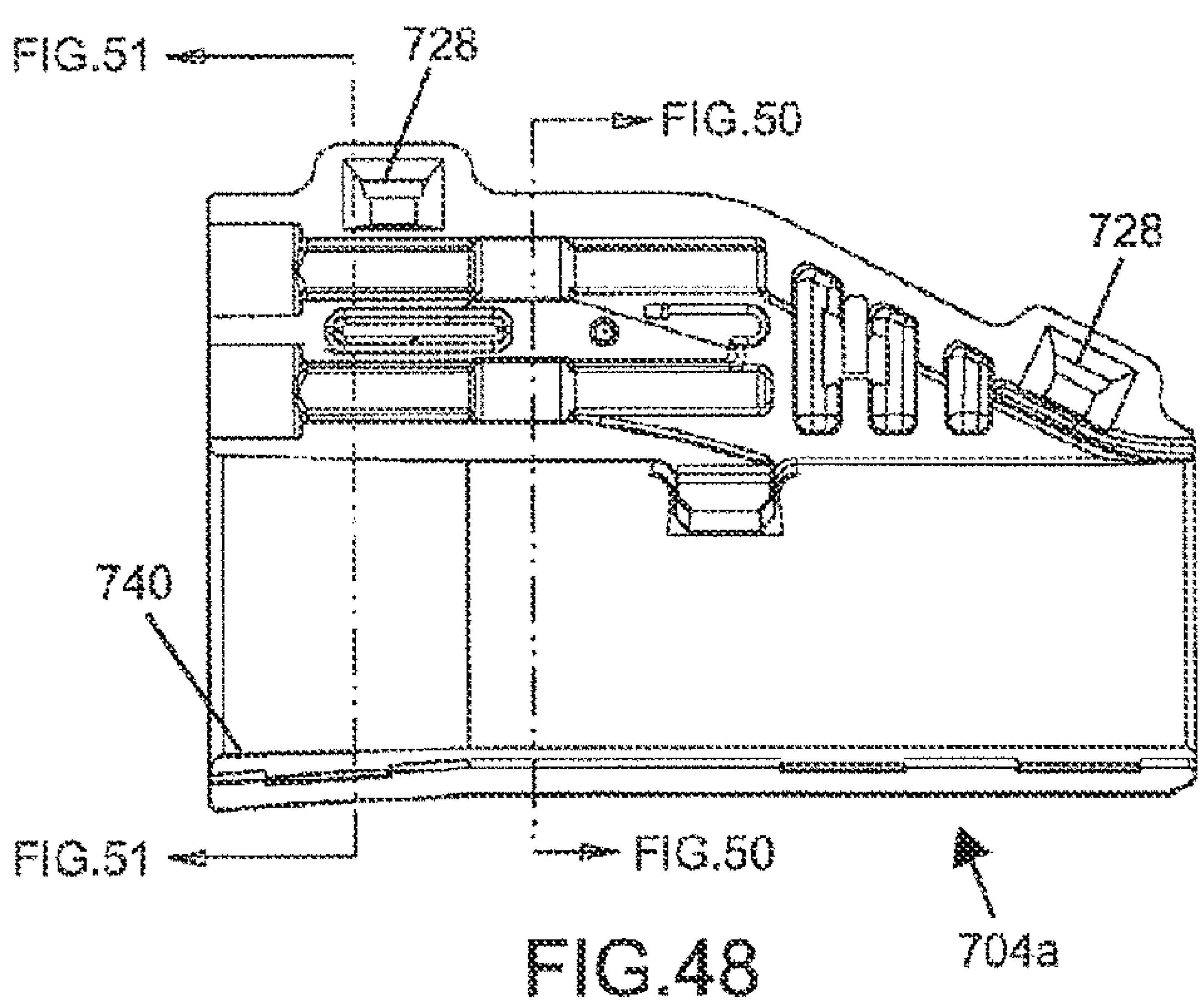


FIG.48

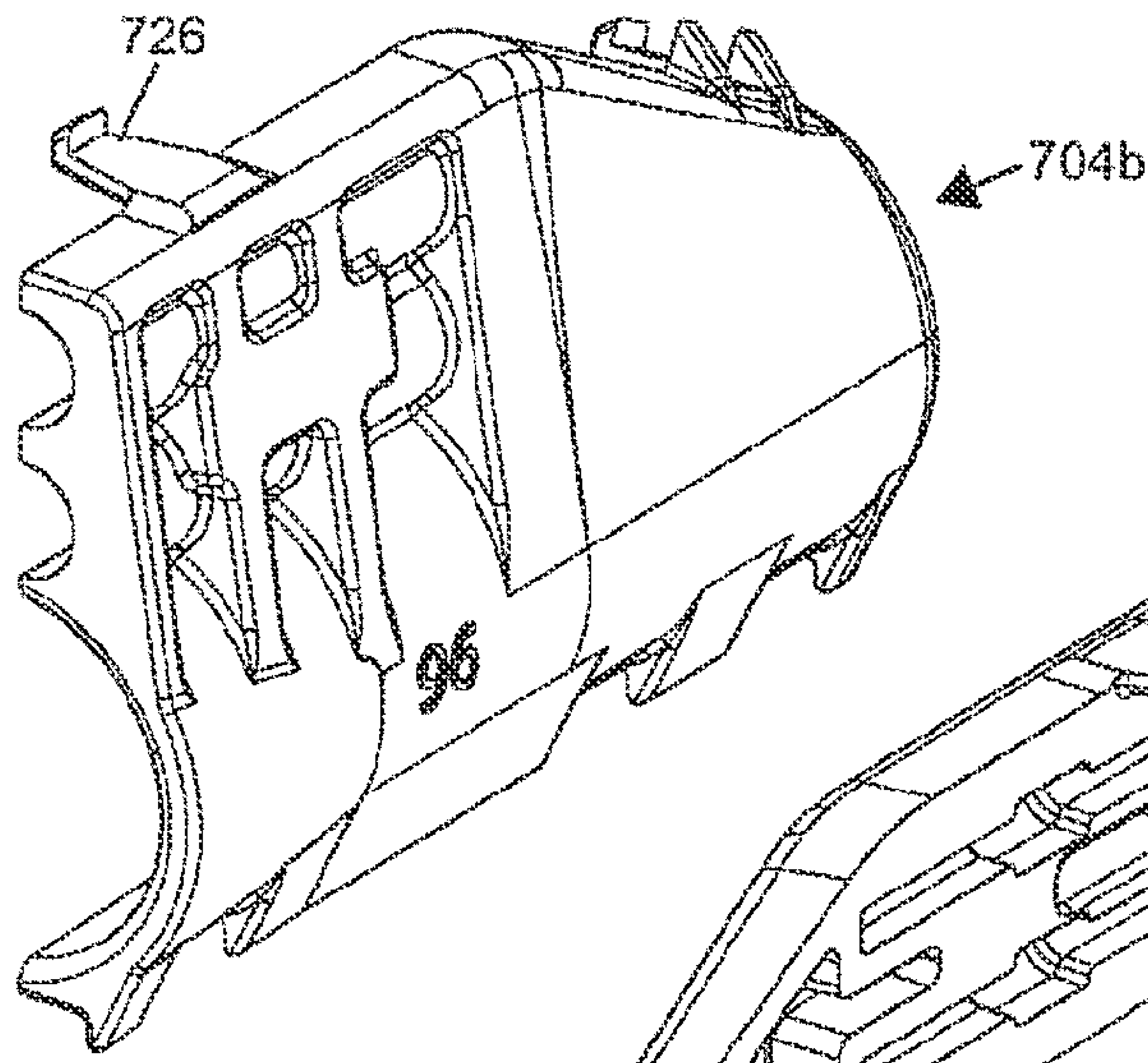


FIG.52

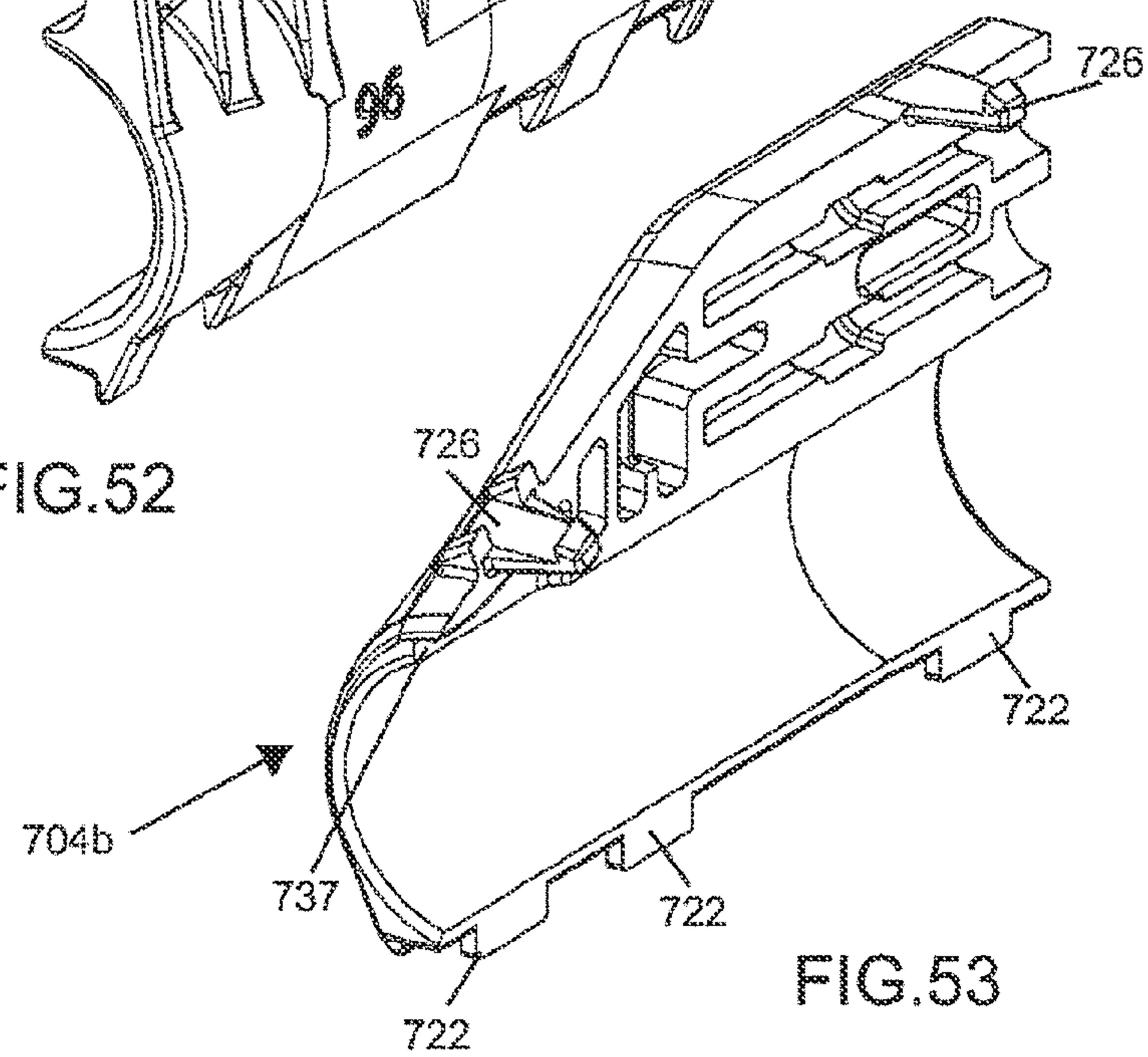
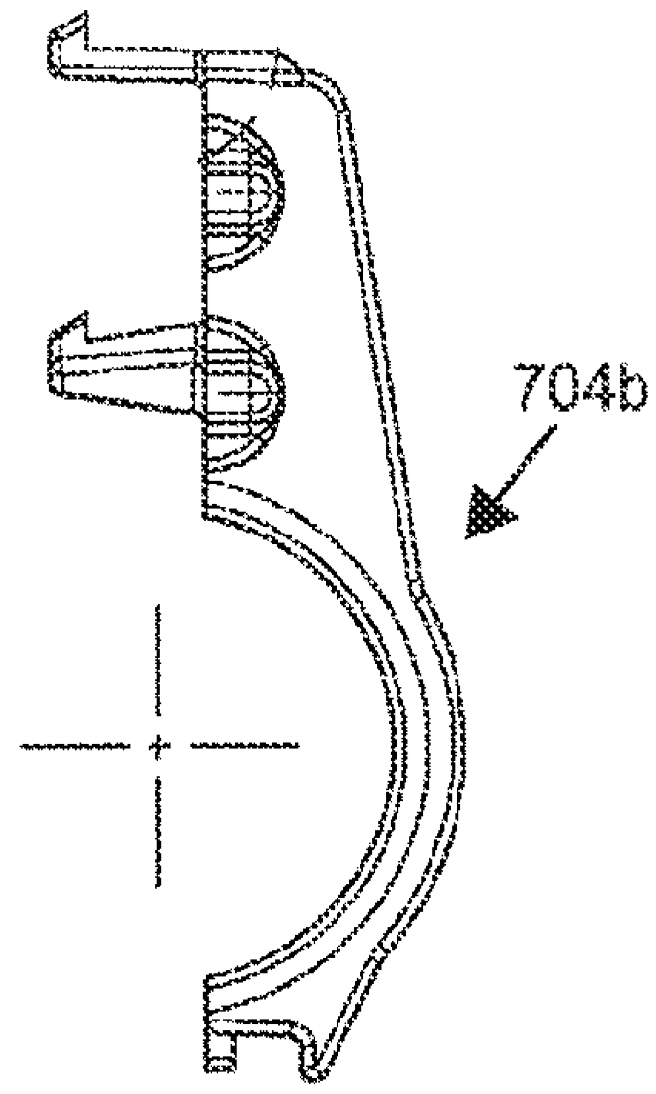


FIG.53

FIG.59



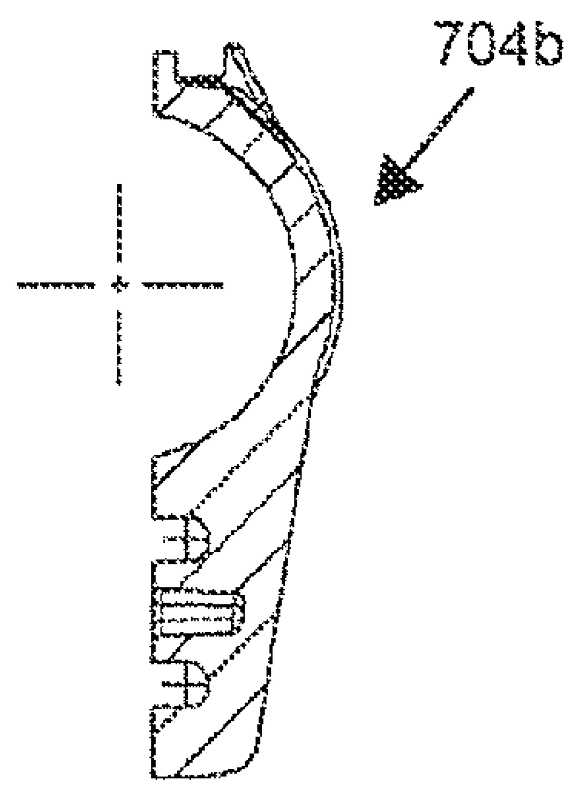


FIG.58

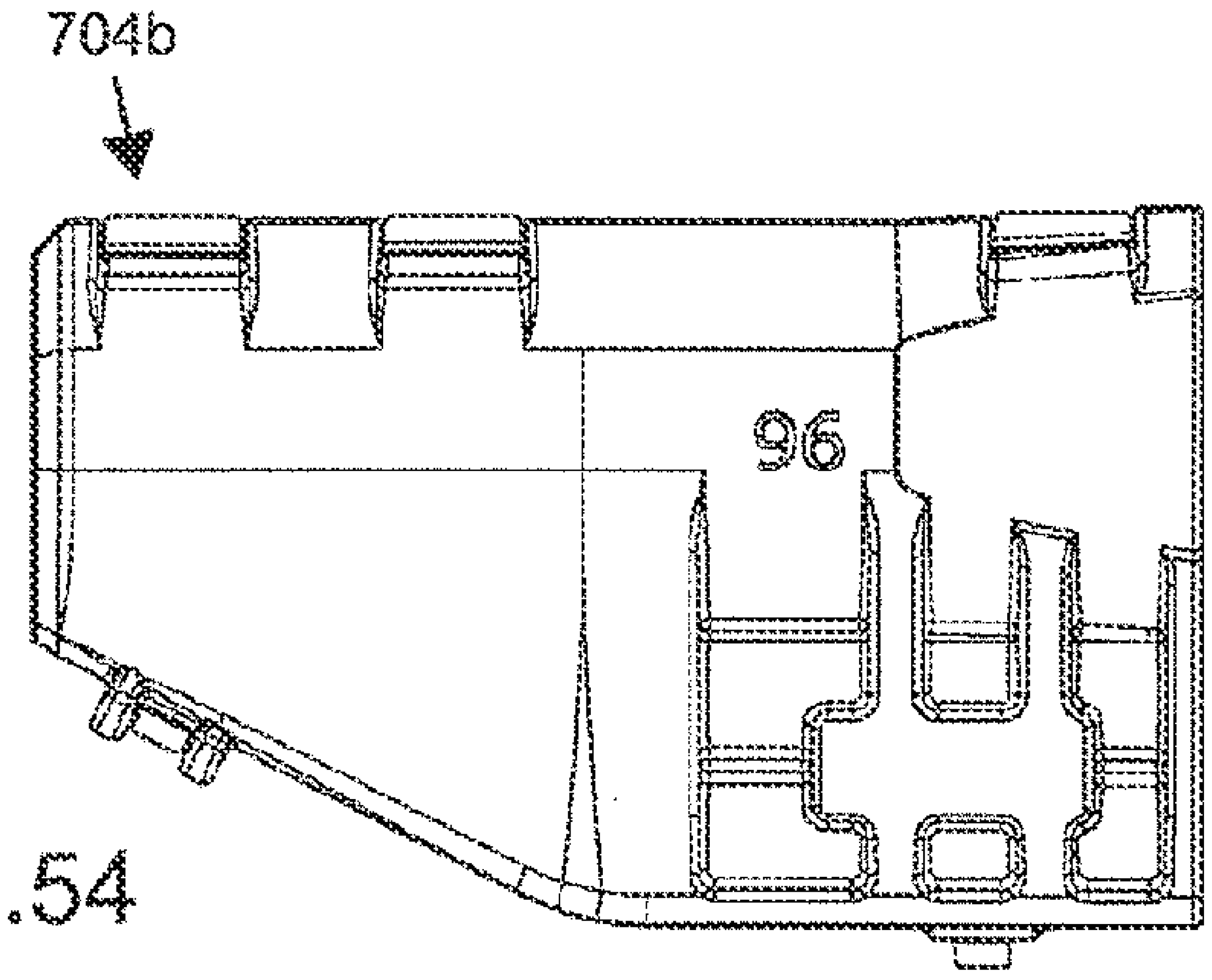


FIG.54

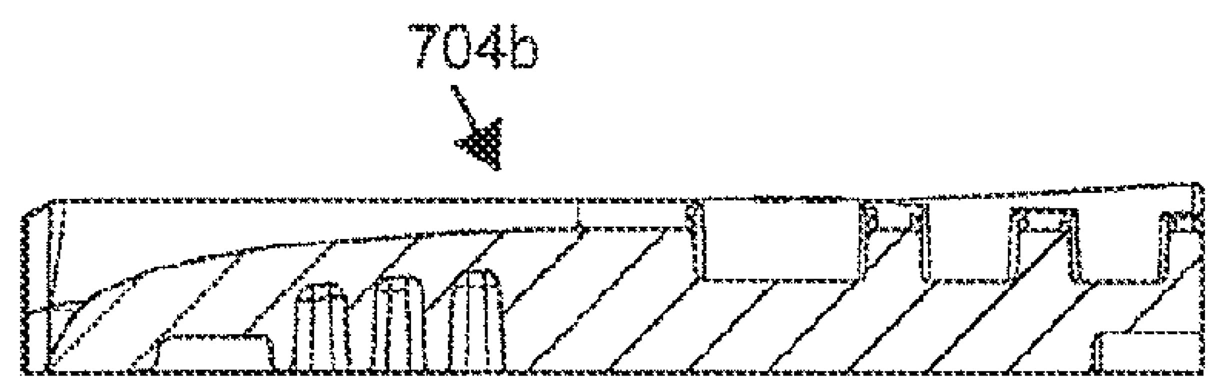


FIG.56

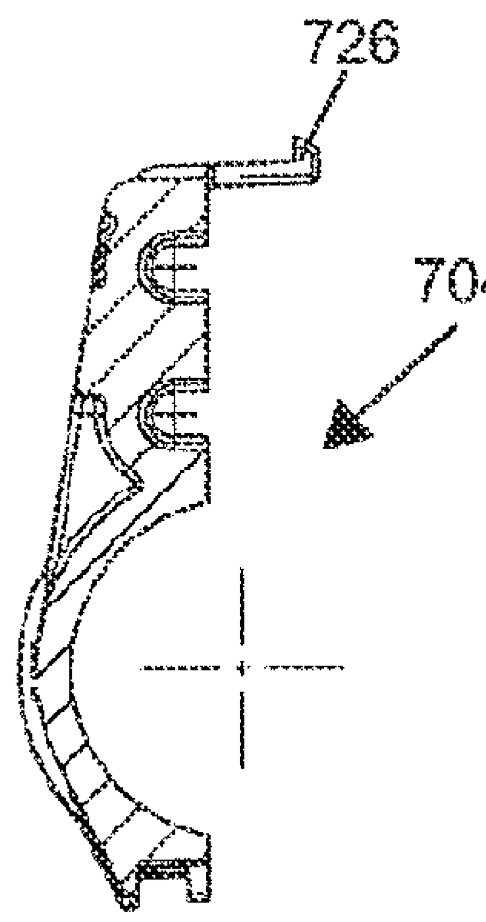


FIG.57

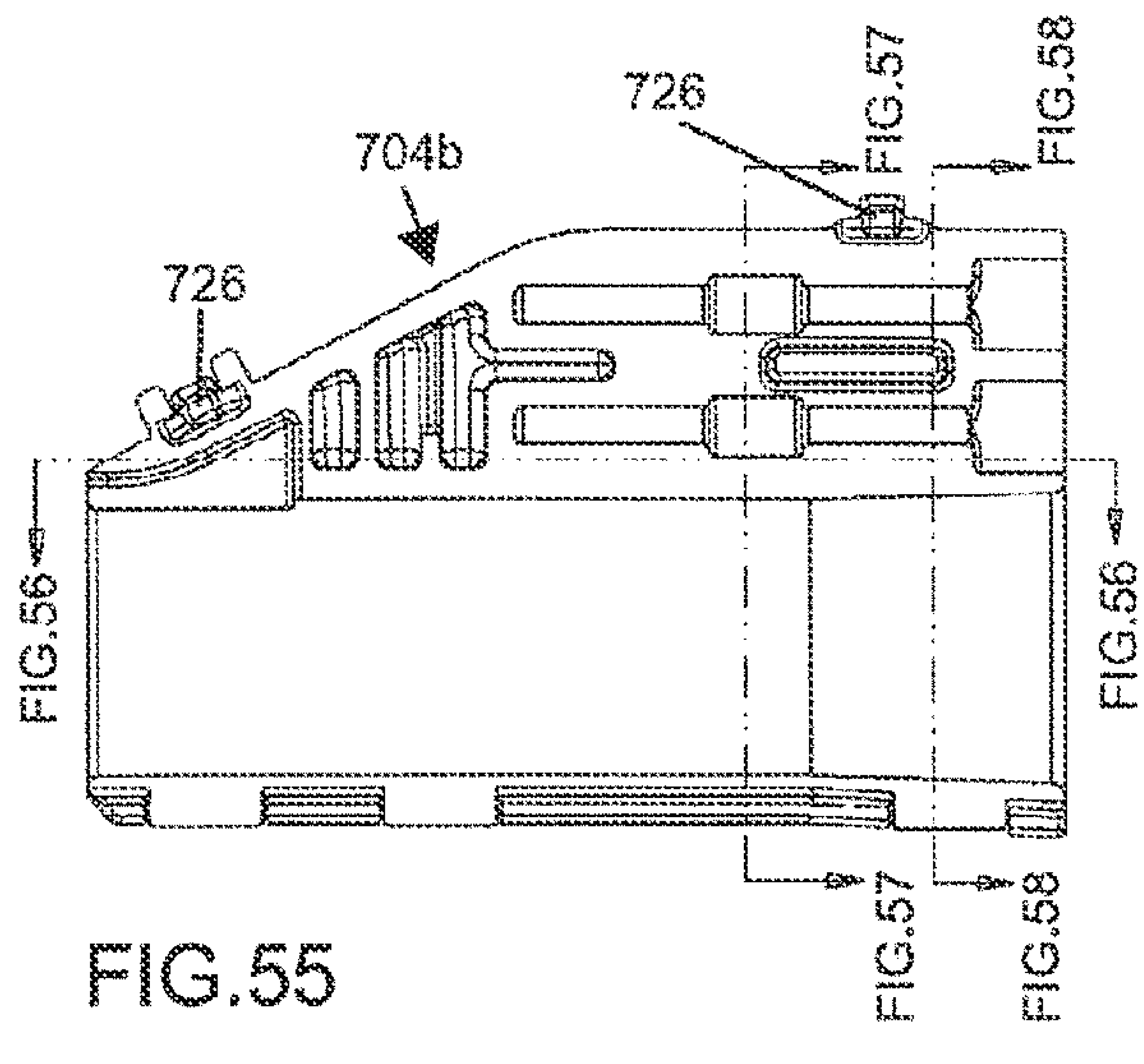


FIG.55

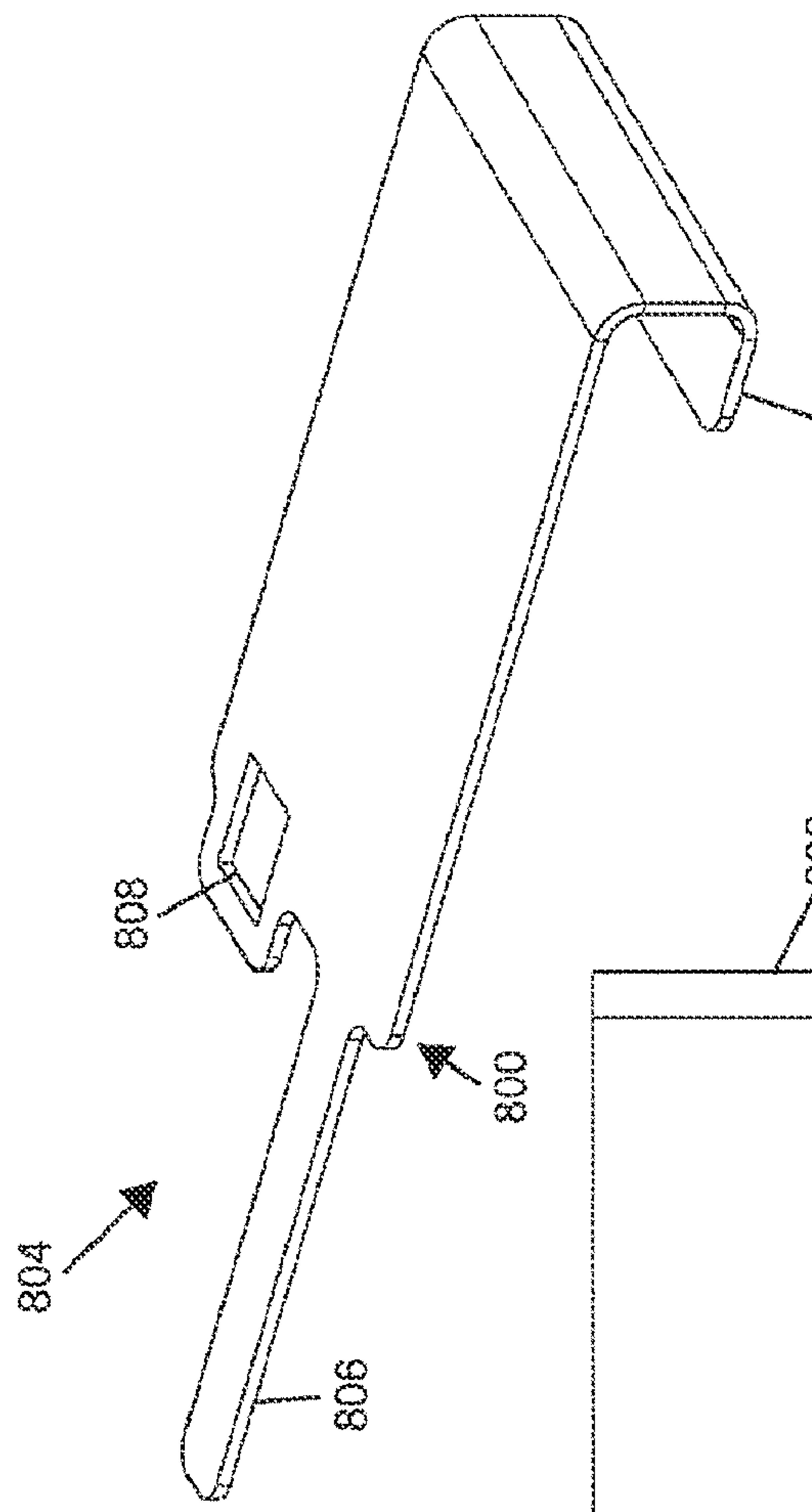


FIG.63

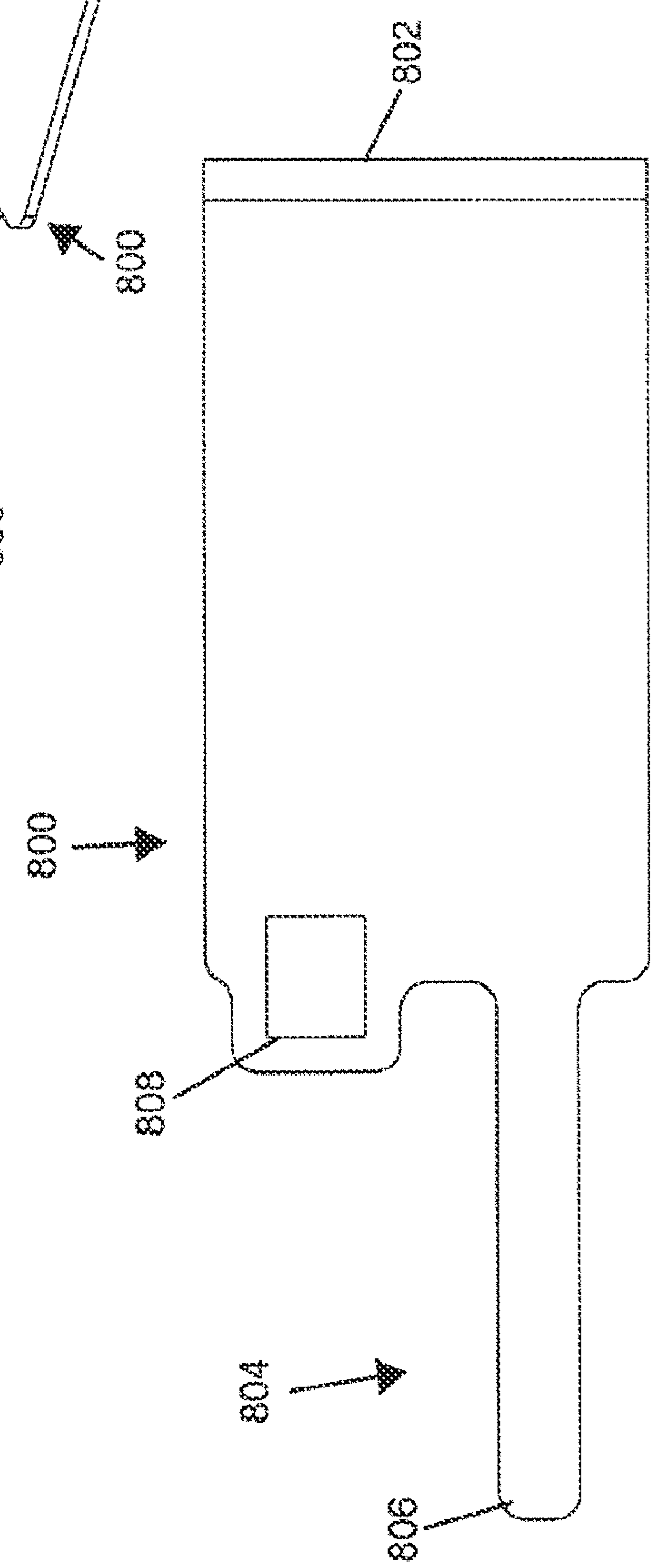


FIG.60

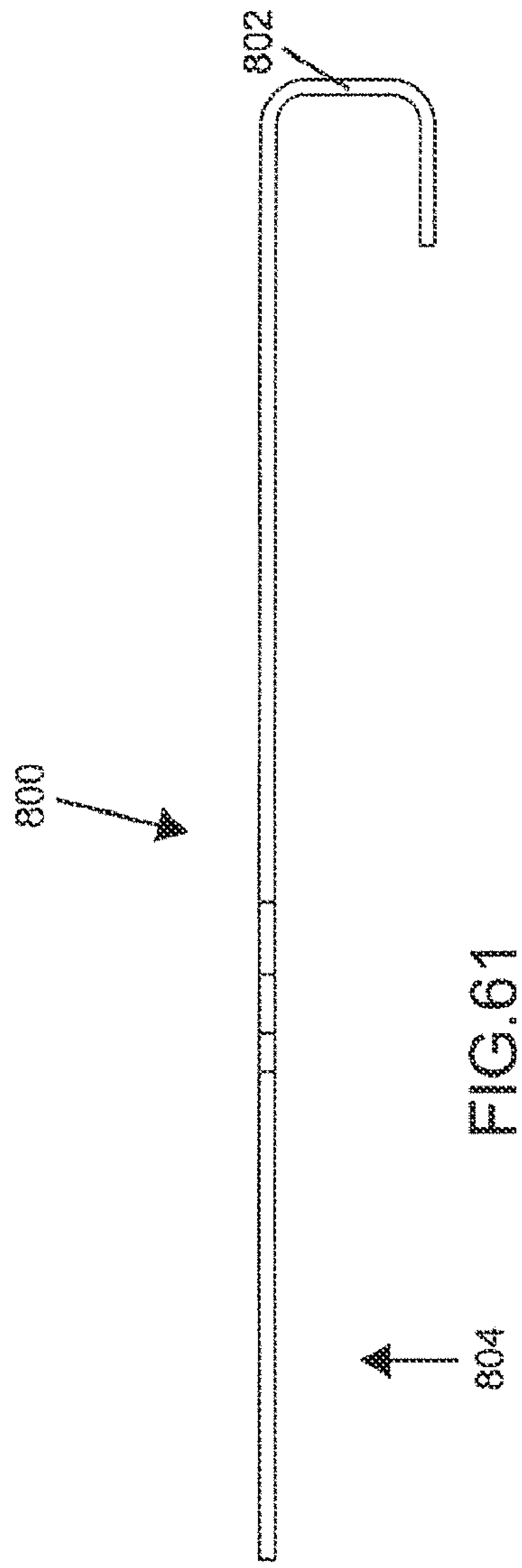


FIG.61

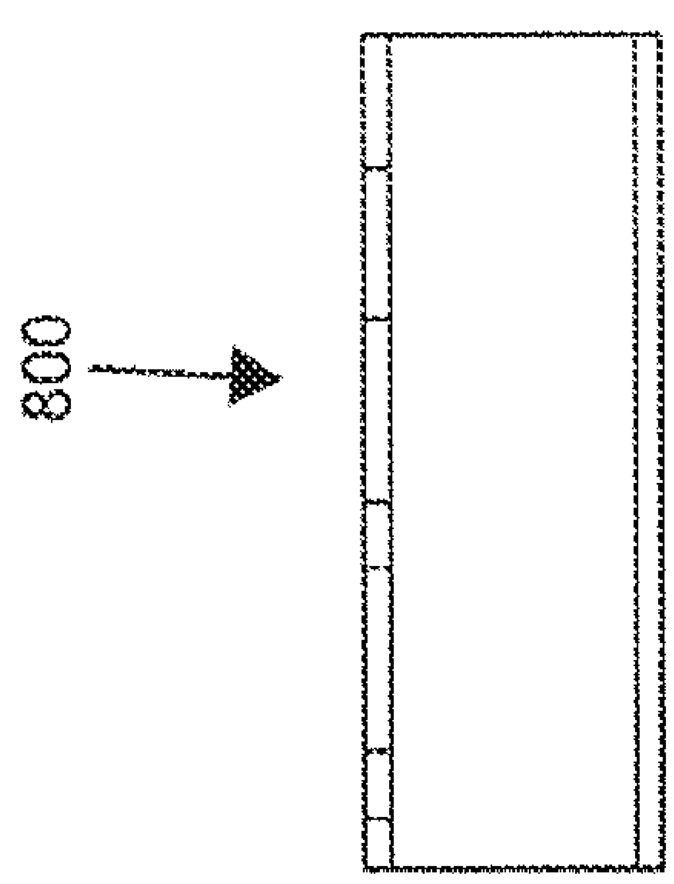
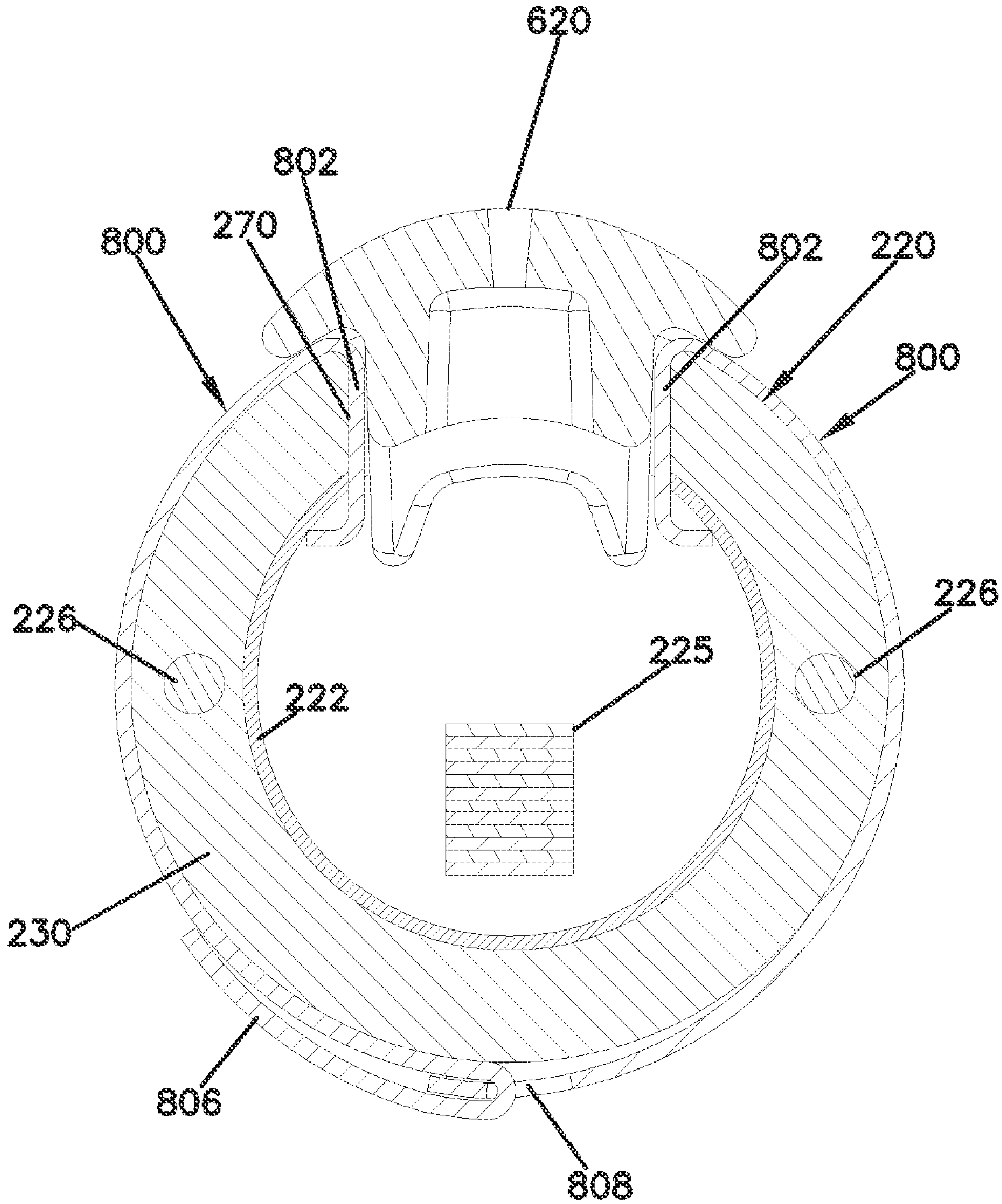


FIG.62

FIG. 64



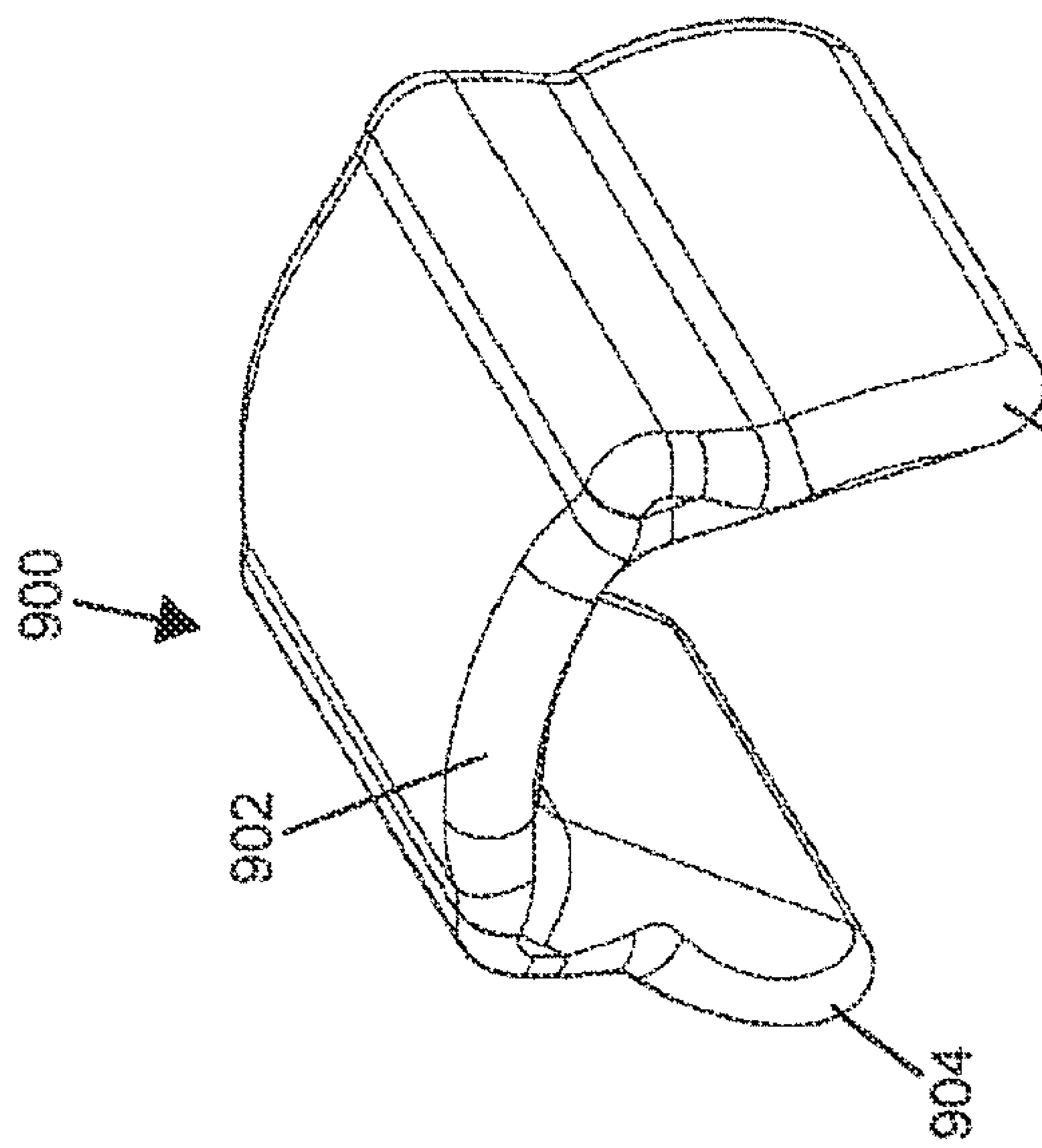


FIG.67

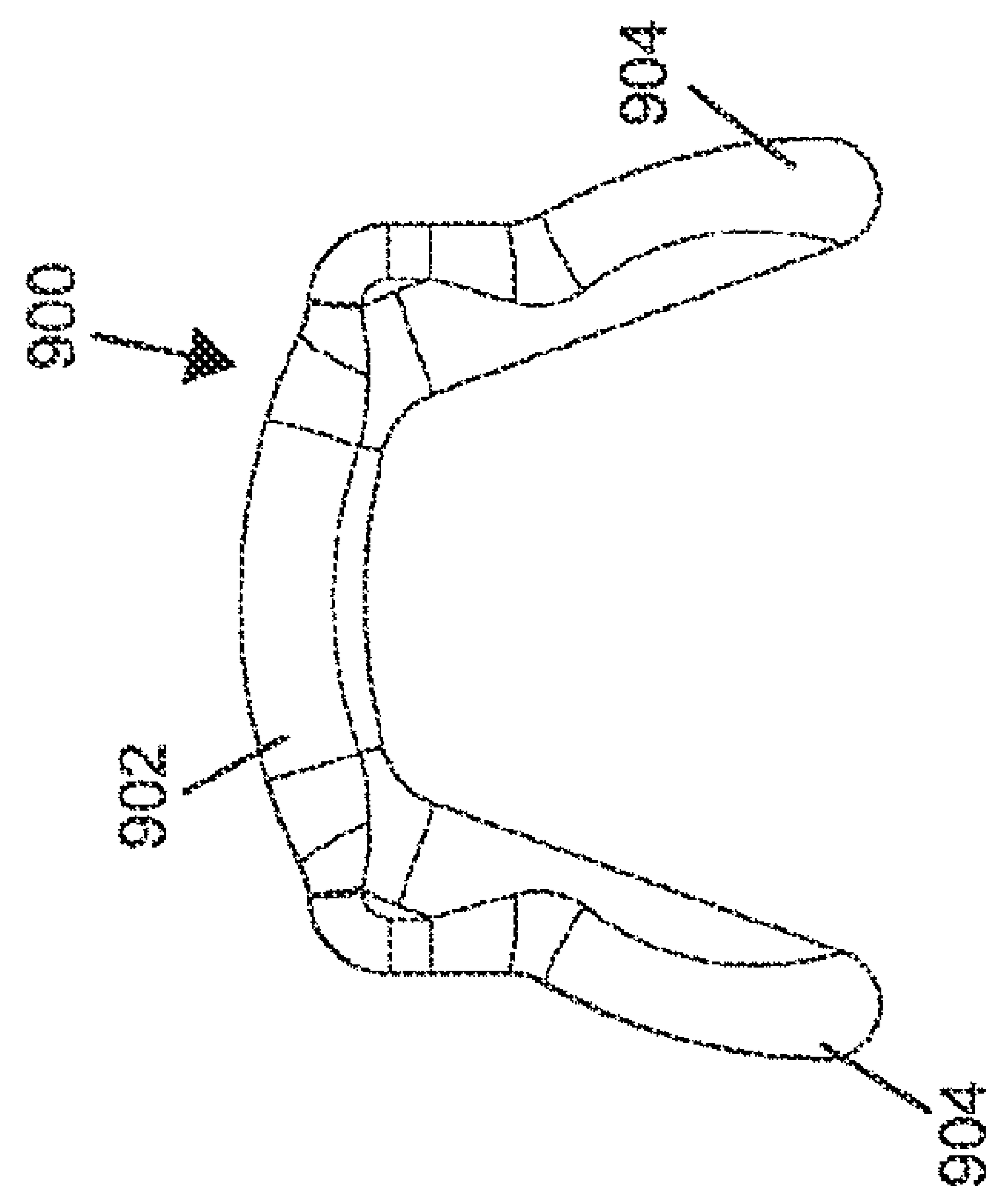


FIG.65

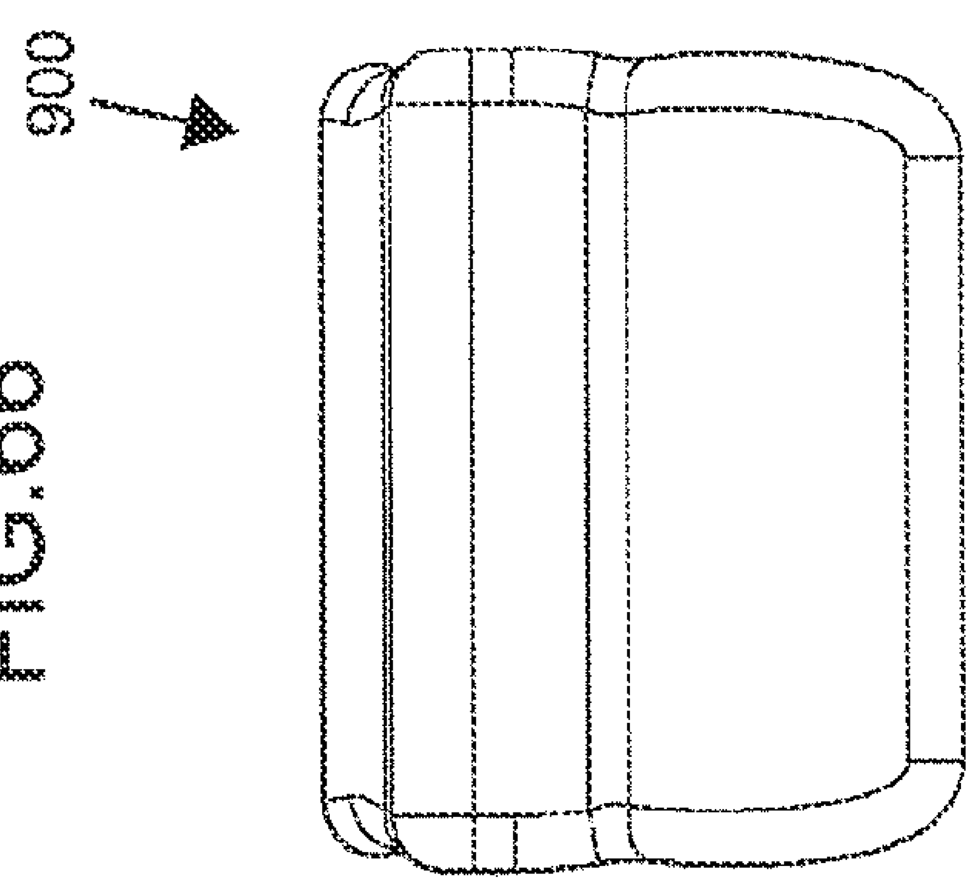
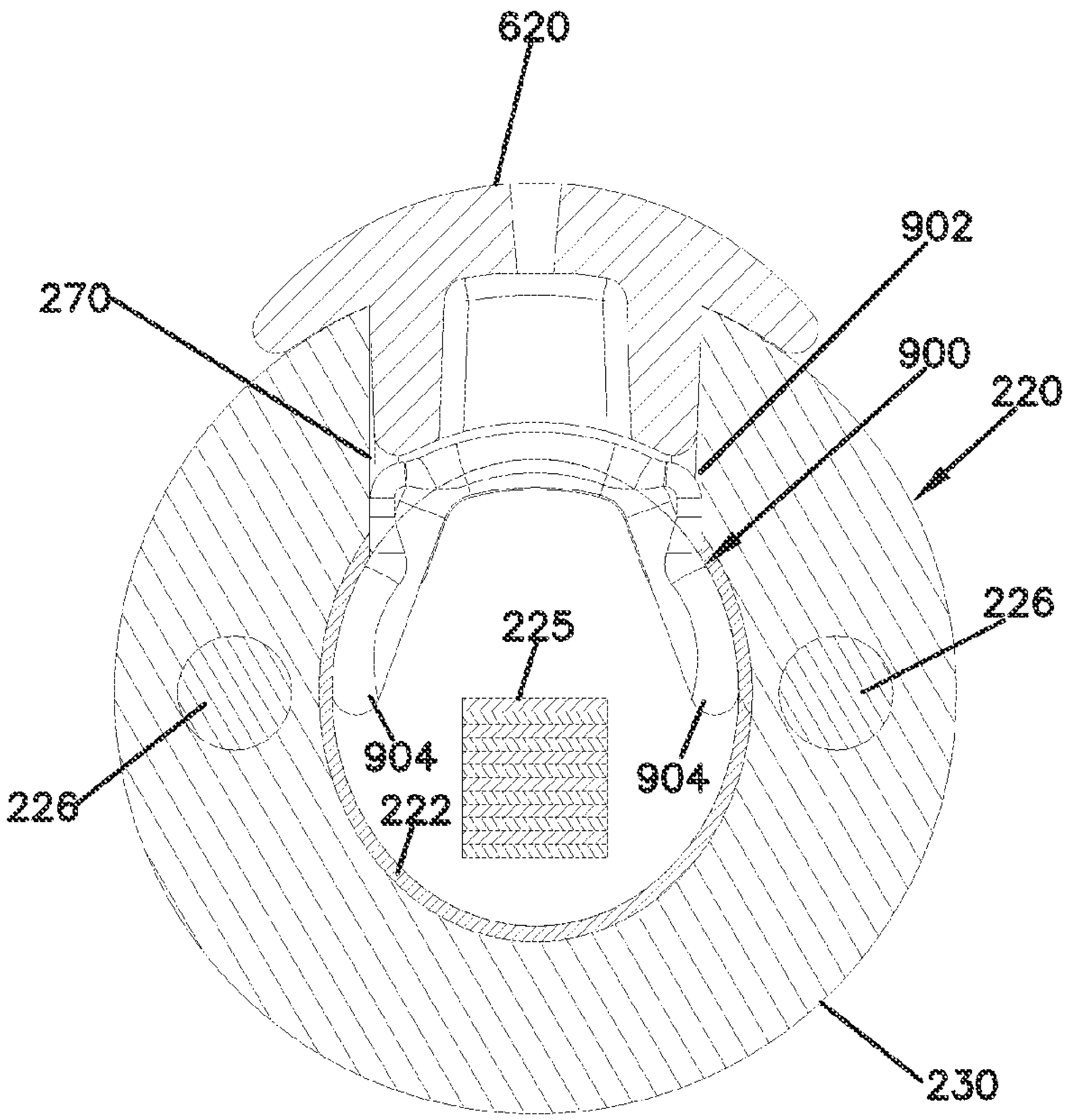


FIG.66

FIG. 68



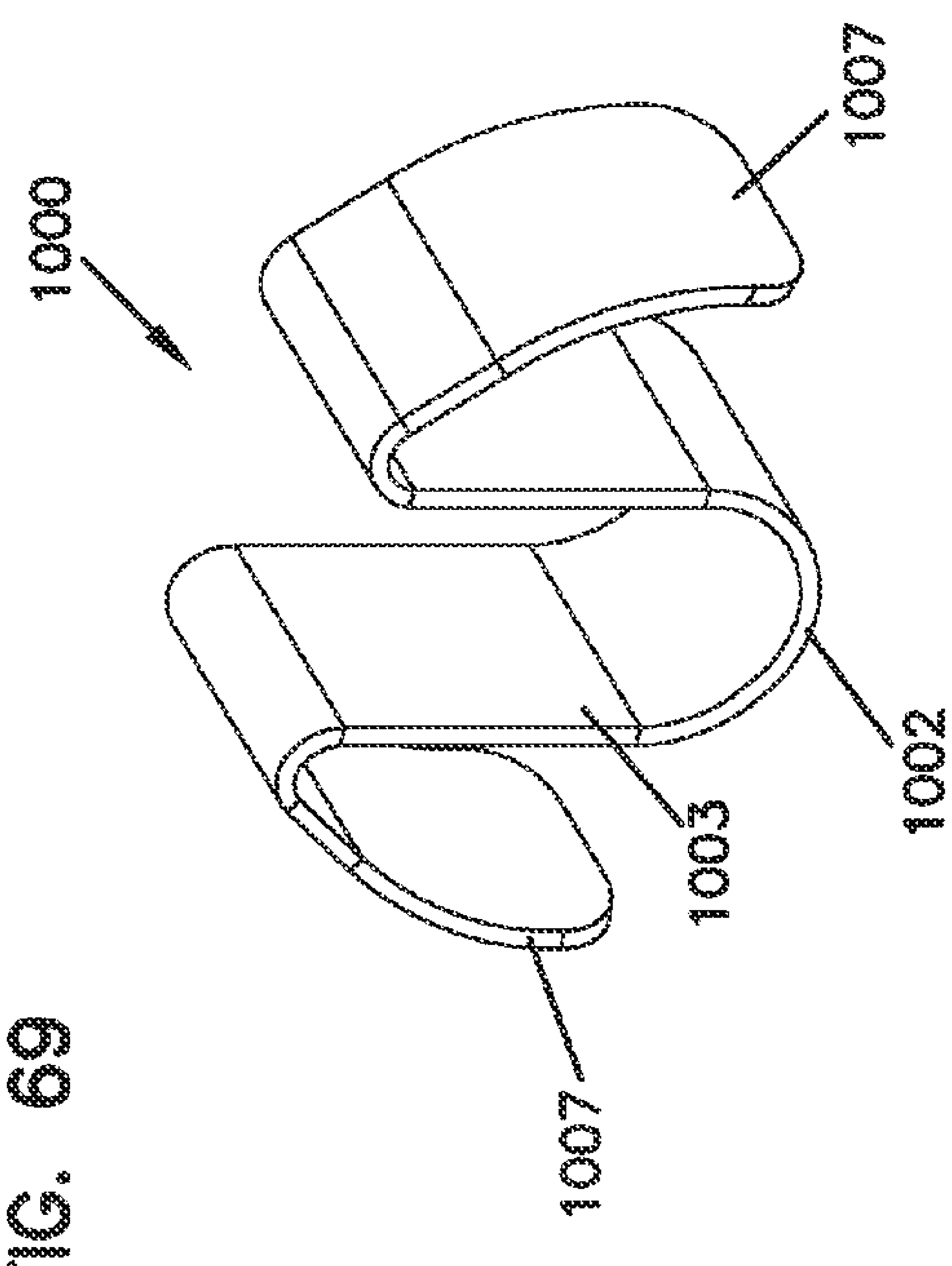


FIG. 69

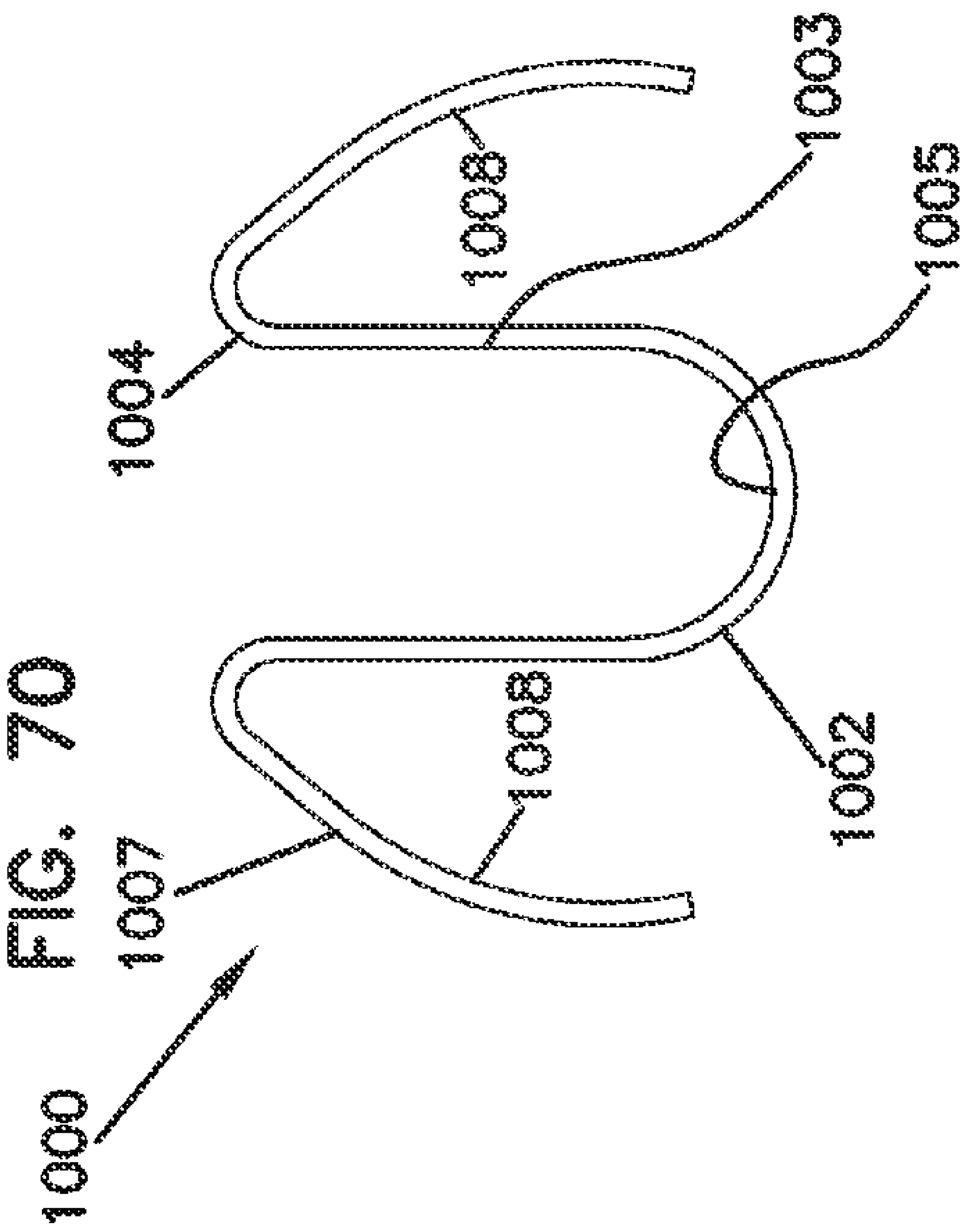


FIG. 70

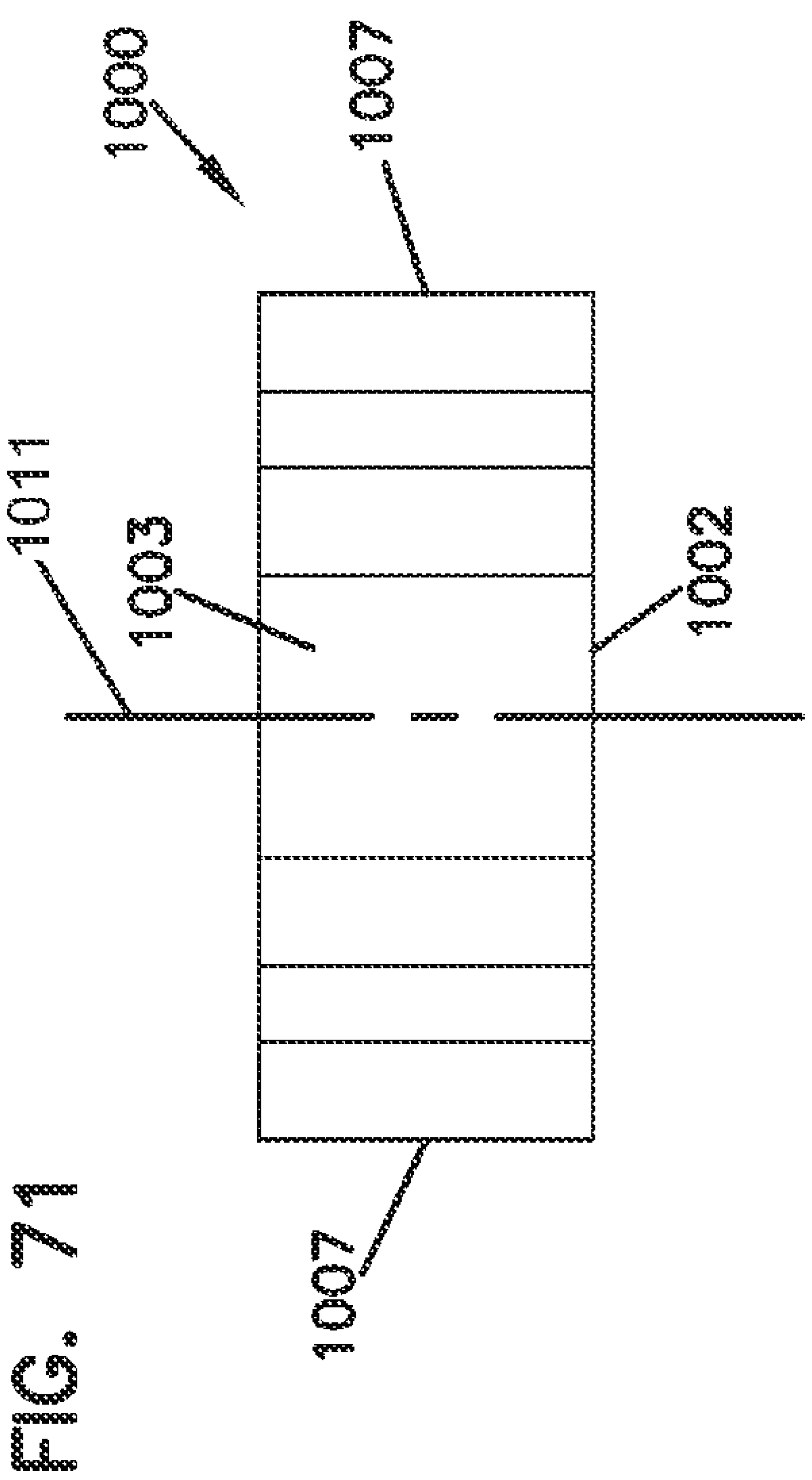


FIG. 71

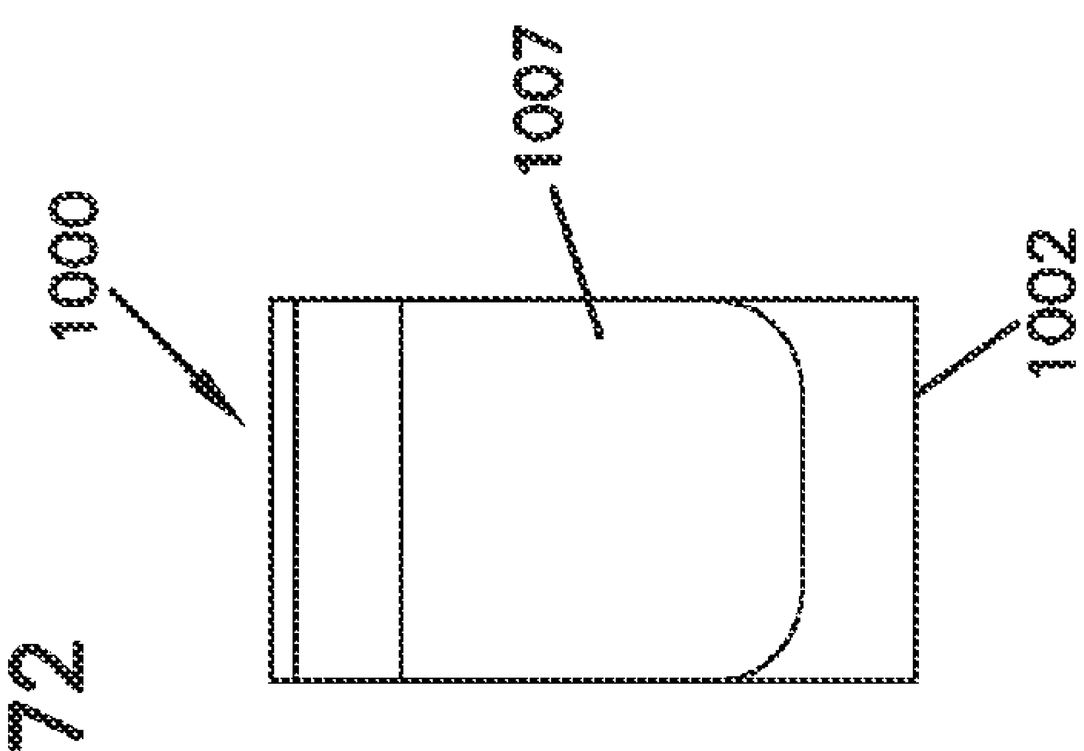
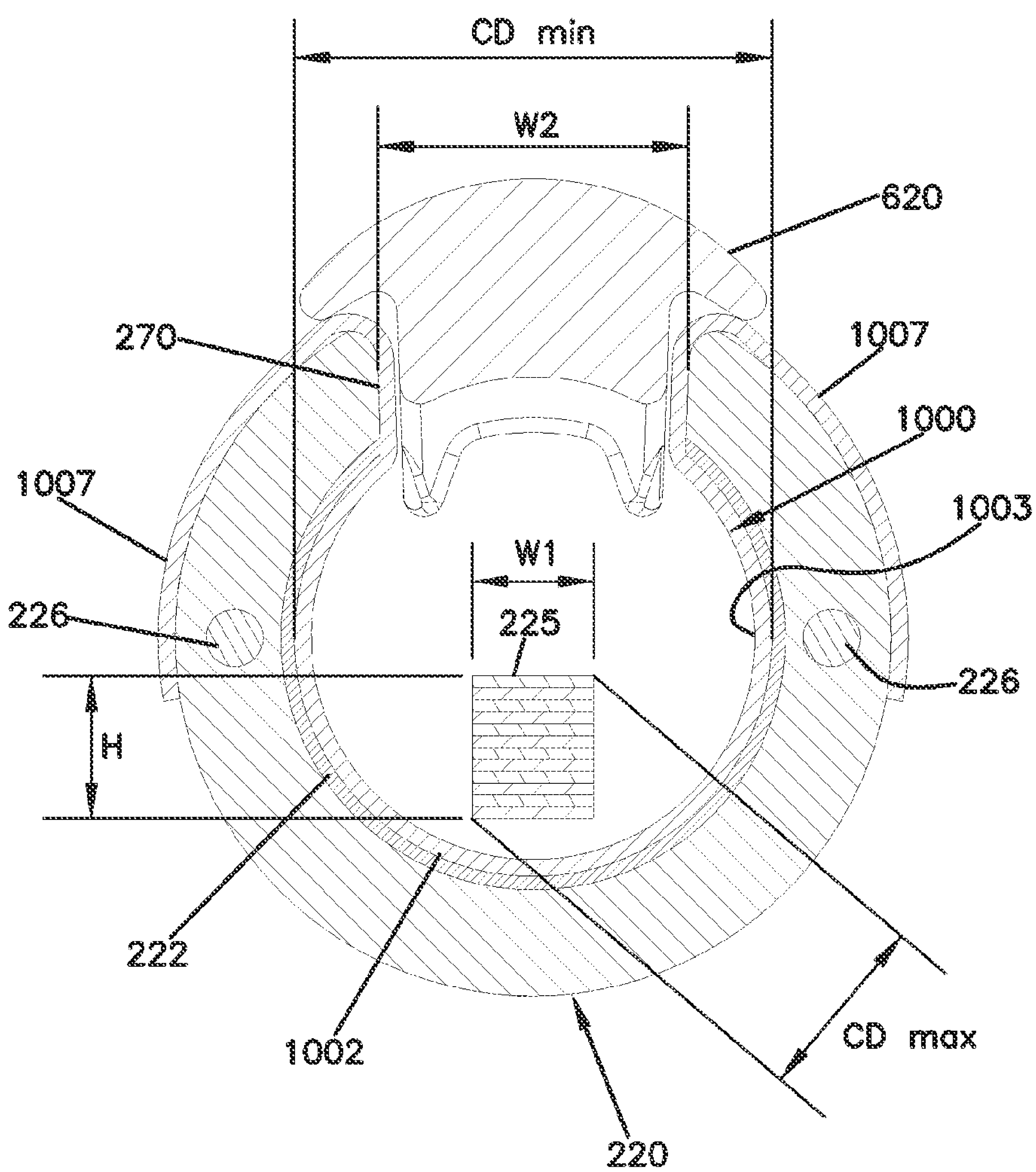


FIG. 72

FIG. 73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1007
1000
1007
1003
W1
225
226
226
H
222
1002
220
CD max

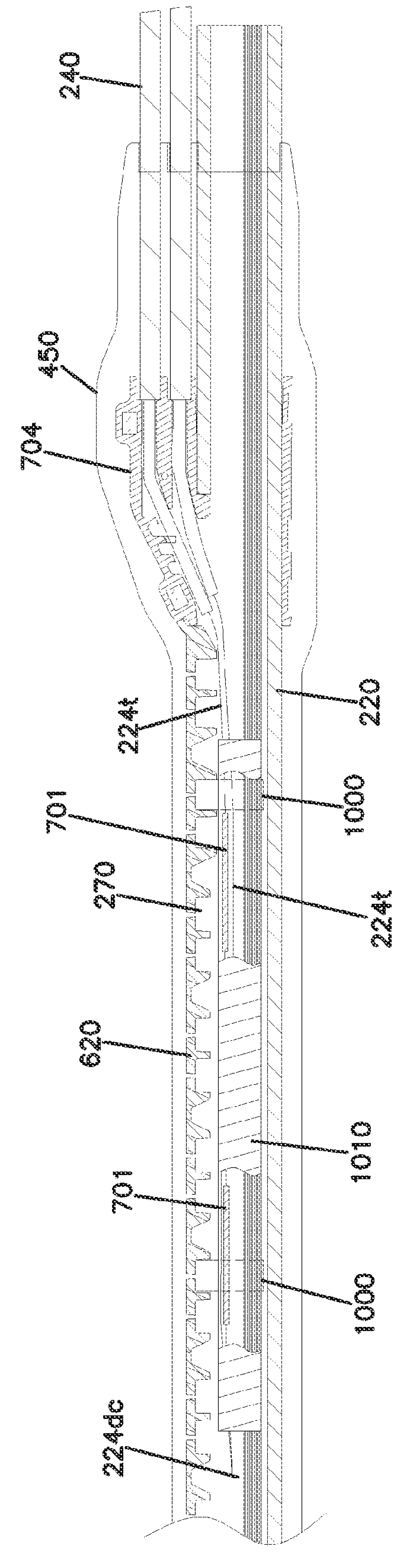

FIG. 74

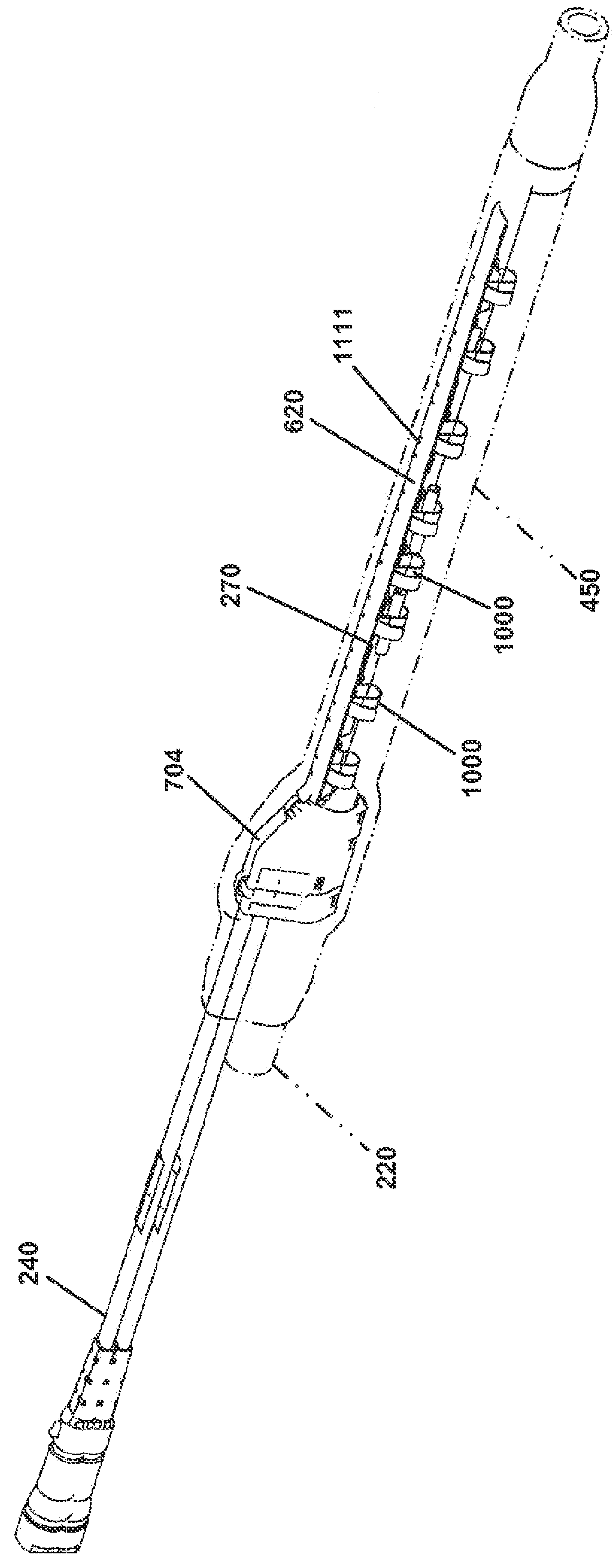

FIG. 75

FACTORY SPLICED CABLE ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Ser. No. 60/976,054, filed Sep. 28, 2007. This application is also a continuation-in-part of U.S. patent application Ser. No. 11/837,862, filed Aug. 13, 2007, now U.S. Pat. No. 7,454,106, issued Nov. 18, 2008, which claims the benefit of U.S. Provisional Patent Application Ser. No. 60/950,521, filed Jul. 18, 2007 and U.S. Provisional Patent Application Ser. No. 60/837,481, filed Aug. 14, 2006. All of the aforementioned patent applications are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

The principles disclosed herein relate to fiber optic cable systems. More particularly, the present disclosure relates to fiber optic cable systems having main cables and branch cables.

BACKGROUND

Passive optical networks are becoming prevalent in part because service providers want to deliver high bandwidth communication capabilities to customers. Passive optical networks are a desirable choice for delivering high speed communication data because they may not employ active electronic devices, such as amplifiers and repeaters, between a central office and a subscriber termination. The absence of active electronic devices may decrease network complexity and/or cost and may increase network reliability.

FIG. **1** illustrates a network **100** deploying passive fiber optic lines. As shown in FIG. **1**, the network **100** may include a central office **110** that connects a number of end subscribers **115** (also called end users **115** herein) in a network. The central office **110** may additionally connect to a larger network such as the Internet (not shown) and a public switched telephone network (PSTN). The network **100** may also include fiber distribution hubs (FDHs) **130** having one or more optical splitters (e.g., 1-to-8 splitters, 1-to-16 splitters, or 1-to-32 splitters) that generate a number of individual fibers that may lead to the premises of an end user **115**. The various lines of the network can be aerial or housed within underground conduits (e.g., see conduit **105**).

The portion of network **100** that is closest to central office **110** is generally referred to as the F1 region, where F1 is the "feeder fiber" from the central office. The F1 portion of the network may include a distribution cable having on the order of 12 to 48 fibers; however, alternative implementations may include fewer or more fibers. The portion of network **100** that includes an FDH **130** and a number of end users **115** may be referred to as an F2 portion of network **100**. Splitters used in an FDH **130** may accept a feeder cable having a number of fibers and may split those incoming fibers into, for example, 216 to 432 individual distribution fibers that may be associated with a like number of end user locations.

Referring to FIG. **1**, the network **100** includes a plurality of break-out locations **125** at which branch cables are separated out from main cable lines. Breakout locations can also be referred to as tap locations, drop cable locations, splice locations or branch locations. Branch cables can also be referred to as drop cables, drop lines, breakout cables or stub cables. Branch cables are often connected to drop terminals **104** that include connector interfaces for facilitating coupling the fibers of the branch cables to a plurality of different subscriber locations.

Branch cables can manually be separated out from a main cable in the field using field splices. Field splices are typically housed within sealed splice enclosures. Manual splicing in the field is time consuming and expensive.

As an alternative to manual splicing in the field, pre-terminated cable systems have been developed. Pre-terminated cable systems include factory integrated breakout locations manufactured at predetermined positions along the length of a main cable (e.g., see U.S. Pat. Nos. 4,961,623; 5,125,060; and 5,210,812). However, existing pre-terminated cable systems can be expensive because extra connectors at intermediate connection locations are often used. Moreover, the installation of pre-terminated cables can be difficult. For example, for underground applications, pre-terminations can complicate passing pre-terminated cable through the underground conduit typically used to hold fiber optic cable (e.g., 1.25 inch inner diameter conduit). Similarly, for aerial applications, pre-terminations can complicate passing pre-terminated cable through aerial cable retention loops.

SUMMARY

Certain aspects of the disclosure relate to fiber optic cable systems, packaging configurations and methods that facilitate the effective use and installation of pre-terminated fiber optic cable.

A variety of additional inventive aspects will be set forth in the description that follows. The inventive aspects can relate to individual features and to combinations of features. It is to be understood that both the forgoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the broad inventive concepts upon which the embodiments disclosed herein are based.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a prior art passive fiber optic network;

FIG. **2** is a cross-sectional view of an example distribution cable according to one embodiment of the present disclosure;

FIG. **3** is a cross-sectional view of an example tether according to one embodiment of the present disclosure;

FIG. **4** is a schematic view of an example tether coupled to a distribution cable at a breakout location having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **5** is a top view of a distribution cable having a cut having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **6**A is a top view of a tether prepared to be optically coupled to the distribution cable of FIG. **5**;

FIG. **6**B is a top view of the tether of FIG. **6**A including a multi-fiber connector located at the end of the tether;

FIG. **7** is a perspective view of a first breakout assembly installed on a distribution cable at a breakout location having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **8** is a front perspective view of an example jacket support having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **9** is an end view of the jacket support of FIG. **8**;

FIG. **10** is a side view of the jacket support of FIG. **8**;

FIG. **11** is a bottom view of the jacket support of FIG. **8**;

FIG. **12** is a perspective view of the distribution cable of FIG. **7** with an over-mold installed over the breakout location according to one embodiment of the present disclosure;

FIG. **13** is a perspective view of a second breakout assembly installed on a distribution cable at a breakout location having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **14** is a side view of an example transition block according to one embodiment of the present disclosure;

FIG. **15** is a perspective view of the transition block of FIG. **14**;

FIG. **16** is an end view of the transition block of FIG. **14**;

FIG. **17** is a partial, schematic view of the breakout assembly of FIG. **13** in which the tether is mounted to a first body member of the transition block and routed into the cut region of the distribution cable and in which the second body member of the transition block has been removed;

FIG. **18** is a perspective view of the distribution cable of FIG. **13** with an over-mold installed over the breakout;

FIGS. **19-23** show another jacket support having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIGS. **24-28** show a further jacket support having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIGS. **29-33** show still another jacket support having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIGS. **34** and **35** are cross-sectional views showing the jacket support of FIGS. **29-33** mounted in a cut region of a distribution cable;

FIG. **36** shows another breakout assembly having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIGS. **37-43** are various views of an anchor block of the breakout assembly of FIG. **36**;

FIGS. **44-51** are various views of a first piece of the anchor block of FIGS. **37-43**;

FIGS. **52-59** are various views of a second piece of the anchor block of FIGS. **37-43**;

FIGS. **60-63** are various views of a cable reinforcing member having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **64** is a cross-sectional view taken transversely through a distribution cable breakout location showing a pair of the reinforcing members of FIGS. **60-63** being used to reinforce the distribution cable;

FIGS. **65-67** are various views of another cable reinforcing member having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **68** is a cross-sectional view taken transversely through a distribution cable breakout location showing the reinforcing member of FIGS. **65-67** being used to reinforce the distribution cable;

FIGS. **69-72** are various views of another cable reinforcing member having features that are examples of inventive aspects in accordance with the principles of the present disclosure;

FIG. **73** is a cross-sectional view taken transversely through a distribution cable breakout location showing the reinforcing member of FIGS. **69-72** being used to reinforce the distribution cable;

FIG. **74** is a cross-sectional view taken transversely through a distribution cable breakout location showing a plurality of the reinforcing members of FIGS. **69-72** spaced apart along the length of the breakout location so as to provide multiple reinforcement locations along the length of the breakout location; and

FIG. **75** is a perspective view of the distribution cable breakout location of FIG. **74**.

DETAILED DESCRIPTION

The present disclosure relates to mid-span breakout arrangements provided on distribution cables. Each breakout arrangement is provided at a breakout location to protect the optical coupling of a tether to a distribution cable. A typical distribution cable includes a relatively large number of fibers (e.g., 72, 144 or more fibers). The fibers are typically organized within ribbons in a central portion of the distribution cable.

For example, FIG. **2** shows an example distribution cable **220** including a central buffer tube **222** enclosing a ribbon stack **225**. Typically, a ribbon stack **225** includes approximately twelve ribbons and each ribbon contains about twelve fibers $\mathbf{224}_{dc}$. For clarity, only twelve fibers $\mathbf{224}_{dc}$ in the ribbon stack **225** are shown. The buffer tube **222** may include dry, water-blocking materials **228**, such as yarn and/or tape. The distribution cable **220** also includes at least one, and preferably two or more, strength members **226** (e.g., flexible rods formed by glass fiber reinforced epoxy) for reinforcing the cable **220**. An outer strength member (not shown), such as aramid fiber/yam (e.g., Kevlar®), can surround the single buffer tube **222** within the jacket **230**. The distribution cable **220** further includes an outer jacket **230** that encloses the ribbon stack **225** and the strength members **226**. Ripcords **232** can be provided for facilitating tearing away portions of the jacket **230** to access the fibers of the ribbon stack **225** within the jacket **230**.

A typical mid-span breakout location is provided at an intermediate point along the length of a distribution cable (e.g., see FIG. **4**). Commonly a tether (e.g., a drop cable or a stub cable) branches out from the distribution cable at the breakout location. The tether most commonly has a fewer number of fibers as compared to the number of fibers provided within the distribution cable. In an example embodiment, the tether has no more than twelve fibers. The tether includes fibers that extend between first and second ends. The first ends of the tether fibers are preferably spliced to selected fibers of the distribution cable at the breakout location. The second ends of the tether fibers can either be connectorized or unconnectorized. In one embodiment, the end of each tether is connectorized with a multi-fiber connector having a multi-fiber ferrule in which the second ends of the tether fibers of the corresponding tether are mounted.

FIG. **3** illustrates a tether cable **240** configured to join to the distribution cable **220** (e.g., at a breakout location **260**). The tether **240** is depicted as having a flat cable configuration. The flat cable configuration includes a central buffer tube **242** containing a plurality of fibers $\mathbf{224}_t$ (e.g., typically one to twelve loose or ribbonized fibers). Strength members **246** (e.g., flexible rods formed by glass fiber reinforced epoxy) are positioned on opposite sides of the central buffer tube **242**. An outer jacket **250** surrounds the strength members **246** and the buffer tube **242**.

In the example shown, the outer jacket **250** includes an outer perimeter having an elongated transverse cross-sectional shape. An additional strength layer **248** (e.g., aramid fiber/yarn) can be positioned between the buffer tube **242** and the outer jacket **250**. As shown at FIG. **3**, the transverse cross-sectional shape includes oppositely positioned, generally parallel sides **252** interconnected by rounded ends **254**.

However, any suitable cable configuration can be utilized for both the distribution cable and the tether cable.

Referring now to FIG. **4**, one or more tethers **240** can optically couple to a distribution cable **220**. Each tether **240** branches outwardly from the distribution cable **220** at a breakout location **260**. The breakout location **260** includes a coupling location **280** where selected ribbonized fibers **224**$_{dc}$ of the distribution cable **220** are optically coupled (e.g., spliced) to corresponding fibers **224**$_t$ of the tether **240**. It is preferred for the fibers **224**$_t$ of the tether **240** to be pre-terminated to the fibers **224**$_{dc}$ of the distribution cable **220**. "Pre-terminated" means that the fibers **224**$_t$ are fused (e.g., spliced) or otherwise optically coupled to the fibers **224**$_{dc}$ of the distribution cable **220** at the factory as part of the cable manufacturing process rather than being field terminated. The remainder of the breakout assembly **200** is also preferably factory installed.

In general, the coupling location **280** is recessed within the outer jacket **230** of the distribution cable **220** along with the ribbonized fibers **224**$_{dc}$ and an end portion of the tether buffer tube **242**. Positioning the coupling location **280** within the outer jacket **230** of the distribution cable **220** provides a smaller transverse cross-section of the breakout location **260**.

Referring now to FIG. **5**, to prepare the breakout location **260** on the distribution cable **220**, a portion of the jacket **230** and the buffer tube **222** is first cut away to provide a cut region **270** (e.g., a rectangular access slot cut through the jacket **230** and the buffer tube **222**). The cut region **270** extends along a length L from a first end **272** and a second, opposite end **274**. The ribbon stack **225** is accessible through the cut region **270**. One or more of the ribbons of the ribbon stack **225** are then selected and the fibers **224**$_{dc}$ of the selected ribbons are accessed. With the distribution cable **220** prepared as shown in FIG. **5**, the fibers **224**$_{dc}$ are ready to be terminated to a prepared tether **240**.

To prepare the tether **240** to be incorporated into the breakout assembly **300** (e.g., see FIG. **7**), a portion of the outer jacket **250** is stripped away to expose the central buffer tube **242** and the strength members **246** (see FIG. **6**A). As shown at FIG. **6**A, the central buffer tube **242** and the strength members **246** project outwardly beyond an end **258** of the outer jacket **250**. The strength layer **248** has been removed from around the buffer tube **242**. After removing the outer jacket **250**, an end portion of the central buffer tube **242** is removed to expose the fibers **224**$_t$. FIG. **6**B shows the tether **240** including a multi-fiber connector **251** (e.g., a 12 fiber multi-fiber connector having a ferrule **253** that can receive 12 fibers) located at the end of the tether distal from the breakout location **260**. Once again, the end of the tether **240** prepared to be mechanically and optically coupled to the distribution cable **220** at the breakout location **260** includes end portions of fibers **224**$_t$ exposed from the buffer tube **242**. Also, the jacket **250** has been stripped to expose end portions of the buffer tube **242** and the strength members **246**. A mechanical crimp member **255** can be crimped to exposed end portions of the strength members **246**. In other embodiments, the crimp member can be crimped over the tether jacket **250**.

The prepared tether **240** is optically coupled to the distribution cable **220** at the coupling location **280** using known coupling techniques (e.g., a fusion splice technique). A coupling protector (i.e., a splice protection sleeve) can be positioned over the spliced fibers **224**$_{dc}$, **224**$_t$ at the coupling location **280**. Typically, the coupling protector is configured to heat shrink to fit the fibers **224**. For example, the coupling protector can include a strength member, inner meltable adhesive tube, and polyolefin outer tube. The strength member of the coupling protector can be stainless steel or fiberglass. Example splice protection sleeves are disclosed at U.S. Pat. No. 5,731,051, that is hereby incorporated by reference in its entirety. It will be appreciated that a splice sleeve can hold/protect a single splice or multiple splices. In one embodiment, one splice sleeve is used to hold all of the splices corresponding to a given tether.

The coupling protector is inserted within the cut region **270** of the distribution cable **220** so as to be recessed below/inside the cable jacket **230** as shown in FIG. **4**. In one embodiment, the outer perimeter (i.e., the outer diameter) of the cable jacket **230** defines an outer boundary within which the coupled fibers **224**$_{dc}$, **224**$_t$ are arranged. In a preferred embodiment, an end portion of the tether buffer tube **242** can also be inserted within the outer boundary through the cut region **270**. The buffer tube **242** and coupling protector can be secured using tape, adhesive, or any desired fastener. The tether **240** can be secured to the distribution cable **220** adjacent the cut region **270** using a breakout assembly as described herein.

Referring now to FIGS. **7-12**, one example of a breakout assembly **300** having features that are examples of inventive aspects in accordance with the principles of the present disclosure is shown. In the example shown in FIG. **7**, the breakout assembly **300** includes jacket supports **320**, a fastener **330**, and a spacer **340**. The fastener **330** secures the tether **240** to the distribution cable **220** at the second end **274** of the cut region **270**. In one embodiment, the fastener **330** includes a strip of tape wound around the tether **240** and the distribution cable **220**. In another embodiment, the fastener **330** includes a hose clamp.

The spacer **340** is located at the first end **272** of the cut region **270**. The spacer is generally configured to protrude radially outwardly from the distribution cable a distance of less than about 0.2 inches. In one example embodiment, the spacer **340** includes a strip of tape wound multiple times around the distribution cable **220** adjacent the first end **272** of the cut region **270**. In other embodiments, however, the spacer **340** can include any desired structure configured to protrude radially outwardly from the distribution cable **220**.

The jacket supports **320** are positioned within the cut region **270** to inhibit excess bending of the ribbon stack **225** along the cut region **270**. In the example shown in FIGS. **8-11**, the jacket supports **320** include legs **324** configured to fit within the cut region **270** of the distribution cable **220** and a curved surface **322** configured to extend over the cut region **270**. In general, the jacket supports **320** have a length L' ranging from about 0.5 inches to about 2 inches, a width W' ranging from about 0.25 inches to about 0.75 inches, and a depth D' of about 0.1 inches to about 0.4 inches. Typically, the jacket supports **320** have a length L' of about 1.0 inches, a width W' of about 0.37 inches, and a depth D' of about 0.2 inches.

FIGS. **20-23** and **24-28** respectively show two alternative jacket supports **520***a*, **520***b* adapted for use in reinforcing the cut region **270** of a breakout location. The jacket supports **520***a*, **520***b* have flanges **521***a*, **521***b* that are curved to match the outer diameter of the cable jacket **230**. The jacket supports **520***a*, **520***b* also include legs **524***a*, **524***b* that project outwardly from the flanges **521***a*, **521***b*. The legs **524***a*, **524***b* are sized to fit within the cut region **270**. When installed at the cut region **270**, the legs **524***a*, **524***b* fit within the cut region **270** and the flanges overlap the outer diameter of the cable jacket **230** at opposite sides of the cut region **270**. The leg **524***a* has a length L**1** that is longer than a corresponding length L**2** of the leg **524***b*. The length L**1** is selected so that the leg **524***a* is sufficiently long to extend through the cable jacket **230** and at least partially into the buffer tube **222** when the jacket support **520***a* is mounted at the cut region **270**. The length L**2** is selected so that the leg **524***b* does not extend into the buffer tube **222** when the jacket support **520***b* is mounted at the cut region **270**. To reinforce the full cut region **270**, it is preferred for a plurality of the jacket supports **520***a* and a plurality of the jacket supports **520***b* to be positioned along the length of the cut region **270**. To provide clearance within the cable **220** for the splice sleeves, the jacket supports **520***b* can be mounted at locations of the cut region **270** in which the jacket supports are arranged to cover the splice sleeves. In contrast, the jacket supports **520***a* can be mounted at locations of the cut region **270** that are axially offset from the splice sleeves. Typically, the jacket supports **520***b* will be arranged at a mid-region of the cut region **270**, and the jacket supports **520***a* will be arranged adjacent the ends **272**, **274** of the cut region **270**.

FIGS. **29-33** show another jacket support **620** adapted for use in reinforcing the cut region **270** of a breakout location. The jacket support **620** is a reinforcing strip having a length that generally equals the length of the cut region **270**. The jacket support **620** has a flange **621** that are curved to match the outer diameter of the cable jacket **230**. The jacket support **620** also includes legs **624***a*, **624***b* that project outwardly from the flange **621**. The legs **624***a*, **624***b* are sized to fit within the cut region **270**. When installed at the cut region **270**, the legs **624***a*, **624***b* fit within the cut region **270** and the flange **621** overlaps the outer diameter of the cable jacket **230** at opposite sides of the cut region **270**. The leg **624***a* has a length L**1** that is longer than a corresponding length L**2** of the leg **624***b*. The length L**1** is selected so that the leg **624***a* is sufficiently long to extend through the cable jacket **230** and at least partially into the buffer tube **222** (see FIG. **34**) when the jacket support **620** is mounted at the cut region **270**. The length L**2** is selected so that the leg **624***b* does not extend into the buffer tube **222** (see FIG. **35**) when the jacket support **620** is mounted at the cut region **270**. Flex locations **626** are provided between the legs of the jacket support **620** to allow the jacket support **620** to flex with the distribution cable **220**. When assembled at the cut region **270**, splice sleeves are preferably mounted beneath the legs **640***b* to provide clearance for the splice sleeves.

The breakout assembly **300** also includes an over-mold **350** that encloses and seals the cut region **270** of the distribution cable **220** from the fastener **330** to the ends of the tether strength members **246** (e.g., see FIG. **12**). In certain embodiments, a wrap of heat resistant tape (e.g., silicone tape) can provide an intermediate layer between the distribution cable **220** and the over-mold **350**.

The over-mold **350** is preferably made of a flexible polymer plastic material. It is preferred for the over-mold **350** to be sized with a cross sectional shape sufficient to allow the breakout location to be readily passed through a one and one-half inch inner diameter conduit or a one and one-quarter inch diameter conduit. In certain embodiments, the breakout location **260** has a cross sectional area that can be passed through a one inch inner diameter conduit.

Referring now to FIGS. **13-18**, an alternative example of a breakout assembly **400** having features that are examples of inventive aspects in accordance with the principles of the present disclosure is shown. The breakout assembly **400** includes a coupling protector (e.g., as described above) positioned over the fibers $\mathbf{224}_{dc}$, $\mathbf{224}_{t}$ at the coupling location **280**.

In the example shown in FIG. **13**, the breakout assembly **400** includes at least one jacket support **420** and a transition block **430**. In general, the jacket supports **420** resemble the jacket supports **320** discussed above with reference to FIGS. **7-12**. In a preferred embodiment, three jacket supports **420** are provided in the cut region **270** of the distribution cable **220**. For clarity, two jacket supports **420** are shown in FIG. **13**.

The transition block **430** secures the tether **240** to the distribution cable **220** at the second end **274** of the cut region **270**. The strength members **246** of the tether **240** can be secured to the transition block **430** to strengthen the mechanical interface between the tether **240** and the distribution cable **220**. The transition block **430** can also provide a path along which the tether buffer tube **242** can be routed into the cut region **270** of the distribution cable **220**.

In certain embodiments, the transition block **430** includes two body members configured to secure together. In some embodiments, the two body members are mirror-images of one another. In other embodiments, however, one of the body members is wider than the other body member to facilitate mounting the tether **240** to the wider body member. For example, FIGS. **14-16** illustrate a first body member **430**A configured to couple to a narrower body member (not shown) to form the transition block **430** shown in FIG. **13**.

The body member **430**A extends along a length L" from a first end **431** to a second, opposite end **433**. The body member **430**A has a top side **437** and a bottom side **439**. The bottom side **439** of the body member **430**A defines a first channel **432** configured to receive the outer jacket **230** of the distribution cable **220**. The first channel **432** extends substantially linearly from the first end **431** to the second end **433** of the body member **430**A.

In general, the body member **430**A has a length L" ranging from about 1.5 to about 3.0 inches, a width W" ranging from about 0.25 inches to about 1.0 inches, and a depth D" ranging from about 0.75 to about 1.25 inches. In a preferred embodiment, the body member **430**A has a length L" of about 2 inches, a width W" of about 0.4 inches and a depth D" of about 1 inch. The transition block **430** has a width equal to the width W" of the first body member **430**A and the width of the second body member (not shown). In one example embodiment, the transition block **430** has a width of about 0.7 inches.

The top side **437** of the body member **430**A defines a second channel **434** configured adjacent the first end **431** to extend generally parallel with the first channel **432** and configured adjacent the second end **433** to taper downwardly to the first channel **432**. A separating member **438** extends between and defines the first and second channels **432**, **434**. The separating member **438** can include a fastening member **436** configured to engage with a corresponding fastening member on the second body member (not shown). In a preferred embodiment, the fastening member **436** can include a hole configured to receive a protruding fastening member on the second body member.

As shown in FIG. **17**, the second channel **434** is configured to receive the tether **240** at the first end **431** and to route the tether **240** into the cut region **270** of the distribution cable **220**. In a preferred embodiment, the second channel **434** is configured to receive the outer jacket **250** of the tether **240** at the first end **431** (see FIG. **17**). In some embodiments, the strength members **246** of the tether **240** can be secured to the body member **430**A adjacent the tapered portion of the second channel **434** (see FIG. **17**). For example, the second channel **434** can include a pair of strength member receptacles **435** for receiving the strength members **246**. The strength members **246** can be adhesively bonded within the receptacles **435**. Further, a pocket **447** can be provided for receiving the mechanical crimp member **255** crimped to the tether to provide a further mechanical coupling between the tether **240** and the transition block **430**. In other embodiments, however, the body member **430**A can be configured to receive and hold the strength members **246** at any point along the second channel **434**.

The transition block **430** also includes further structure for providing an effective mechanical interface with the tether **240**. For example, the second channel **434** includes an end opening **459** sized to match the outer shape of the outer jacket **250** of the tether **240**. Also, a buffer tube receptacle **449** for receiving the exposed buffer tube **242** of the prepared tether **240** is defined between the receptacles **435** that receive the exposed strength members **246** of the prepared tether **240**.

The breakout assembly **400** can also include an over-mold **450** that encloses and seals the cut region **270** of the distribution cable **220** from the transition block **430** to adjacent the first end **272** of the cut region **270** (e.g., see FIG. **18**). In certain embodiments, a wrap of heat resistant tape (e.g., silicone tape) can provide an intermediate layer between the distribution cable **220** and the over-mold **450**.

The over-mold **450** is preferably made of a flexible polymer plastic material. It is preferred for the over-mold **450** to be sized with a cross sectional shape sufficient to allow the breakout location to be readily passed through a one and one-half inch inner diameter conduit or a one and one-quarter inch diameter conduit. In certain embodiments, the breakout location **260** has a cross sectional area that can be passed through a one inch inner diameter conduit.

Referring now to FIG. **36**, an alternative example of a breakout assembly **700** having features that are examples of inventive aspects in accordance with the principles of the present disclosure is shown. The breakout assembly **700** includes two splice protectors **701** (e.g., as described above) positioned over splices between the fibers **224**$_{dc}$, **224**$_t$. It will be appreciated that the fibers **224**$_{dc}$, **224**$_t$ depicted at FIG. **36** are each representative of a plurality of fibers (e.g., 12 fibers in the case of 12 fiber tethers). The breakout assembly **700** also includes the jacket support **620** of FIGS. **29-33**, which is mounted in the cut region **270** of the breakout location. The splice protectors **701** are located within the jacket **230** of the distribution cable **220** at locations beneath the shorter legs **624***b* of the jacket support **620**. The breakout assembly further includes a block **704** that functions to transition the fibers **224**$_t$ from the distribution cable **220** to the tethers **240**, and also functions to anchor the tethers **240** to the distribution cable **220**. The jacket support **620** includes a tab **661** that overlaps the block **704** to resist relative movement between the block **704** and the jacket support **620**. In FIG. **36**, overmold **450** is shown encasing the distribution cable breakout location.

Referring to FIGS. **39-43**, the block **704** includes a cable channel **705** for receiving the distribution cable **220**. The cable channel **705** is generally straight and extends from a first open end **707** to a second open end **709**. The cable channel **705** receives the distribution cable **220** and allows the distribution cable **220** to pass through the block **704**. It will be appreciated that the jacket **230** of the distribution cable **220** cab be adhesively bonded within the channel **705** such that the block **704** is mechanically anchored to the cable **220**.

The block **704** also includes a tether channel arrangement **710** adapted for anchoring two tethers **240** to the block **704**. The tether channel arrangement includes first and second tether channels **712** each adapted for receiving a tether **240**. Similar to previous embodiments, the channels **712** can include structures for mechanically coupling the tethers to the block **704**. For example, the tether channels **712** can include crimp pockets for receiving mechanical crimps coupled to the tethers, strength member receptacles for facilitating bonding the tether strength members to the block **704**, and other structures.

The block **704** has a two piece configuration including pieces **704***a*, **704***b* that interconnect by a hinged, snap fit configuration. A hinge **720** is defined between the pieces **704***a*, **704***b* by tabs **722** of piece **704***b* that fit within openings **724** of piece **704***a*. A snap fit connection is provided between the pieces **704***a*, **704***b* by flexible cantilever latches **726** of piece **704***b* that fit within receivers **728** of piece **704***a*. To mount the block **704** on the distribution cable **220**, the tabs **722** are inserted within the openings **724** and the cable **220** is inserted between the pieces **704***a*, **704***b* in alignment with the cable channel **705**. The two pieces **704***a*, **704***b* are then pivoted toward one another about hinge line **730** thereby capturing the cable **220** within the cable channel **705**. The pieces **704***a*, **704***b* are pivoted toward one another until the cantilever latches **726** snap within the receivers **728** thereby securing the pieces **704***a*, **704***b* together.

The block **704** includes other features for enhancing the breakout location. For example, piece **704***a* includes a lug **733** that fits within the cut region **270** to maintain rotational alignment between the distribution cable **220** and the block **704** during assembly (i.e., the lug prevents fits within the cut region **270** to prevent relative rotation from occurring between the block **704** and the distribution cable **220**). Also, piece **704***a* includes an overlap member **735** that fits within a receptacle **737** of piece **704***b* to minimize any fiber pinch locations that may be present between the pieces **704***a*, **704***b*. Further, piece **704***a* includes an integral hook **739** for receiving the buffer tube **242** of one of the tethers **240** to retain the buffer tube **242** in close proximity to the piece **704***a*.

The cable channel **705** of the block **704** also includes a tapered diameter **740** adjacent the second open end **709**. The tapered diameter **740** enlarges as the channel **705** extends toward the second open end **709**. Prior to assembling the block **704** on the distribution cable **220**, tape is wrapped about the cable at a location slightly offset from the end **274** of the cut region **270**. By mounting the block **704** on the cable **220**, and then sliding the block **704** axially along the cable toward the tape, the tape is received and compressed within the tapered diameter **740** to assist in sealing the second open end **709** of the cable channel **705**.

In each of the above-described breakout arrangements, a cut region or slot was provided in the cable jacket **230** and buffer tube **222**. Because the cable **220** has been compromised, flexing of the cable can cause distortion of the cable cross-section and/or movement of the strength member **226** within the cable **220**. To protect the splice location, further reinforcement can be provided to resist cable distortion and/or strength member movement. FIGS. **60-63** show an example reinforcing member **800** that can be used to further reinforce the cable **220** at the cut region **270**. The reinforcing member **800** is a bendable metal clip having a hook end **802** and a fastening end **804**. The fastening end **804** includes a strap **806** and a strap receiver **808**. In practice, a pair of the reinforcing members **800** are used together to reinforce the cable **220**. As shown at FIG. **64**, the hook ends **802** are inserted through the cut region **270** and hooked over the cut edges of the jacket **230** and the buffer tube **222**. The bodies of the reinforcing members **800** are bent around the outer diameter of the jacket **230** and fastening ends **804** are fastened together at the side of the cable **220** opposite form the cut region **270**. The members **800** are fastened together by inserting the straps **806** through the receivers **808**, and bending the straps **806** while pulling the straps tight. It will be appreciated that one or more of the pairs of reinforcing members **800** can be used to reinforce the cable **220** at the cut region **270**. In one embodiment, a plurality (e.g., 6 or more) of the pairs of reinforcing members **800** are uniformly spaced along the length of the cable **220** that coincides with the cut region **270**.

FIGS. **65-68** show another reinforcing member **900** that can be used to further reinforce the cable **220** at the cut region

270. The reinforcing member **900** is a buffer tube spreader that fits within the buffer tube **222** as shown at FIG. **68** to assist in holding the buffer tube open. The reinforcing member **900** includes an insert portion **902** that fits within the cut region **270**, and spreader wings **904** that angle outwardly from the insert portion **902**. It will be appreciated that one or more of the reinforcing members **900** can be used to reinforce cable **220** at the cut region **270**. In one embodiment, a plurality (e.g., 6 or more) of the reinforcing members **900** are uniformly spaced along the length of the cable **220** that coincides with the cut region **270**. For certain applications, the reinforcing members **800** and **900** can be used separately or in combination with one another to reinforce a distribution cable.

FIGS. **69-73** show another reinforcing member **1000** that can be used to further reinforce the cable **220** at the cut region **270**. The reinforcing member **1000** is a clip that fits within the buffer tube **222**, as shown at FIG. **73**, to assist in holding the buffer tube open. The reinforcing member **1000** can be made of a metal, plastic or other materials suitable for reinforcing the buffer tube **222**. The reinforcing member **1000** includes a central portion **1002** defining a channel **1003** that extends through the reinforcing member **1000** and that defines a pass-through axis **1011**. From an end view as shown at FIG. **70**, the channel having an open side **1004** and a closed side **1005**. When the reinforcing member **1000** is installed within the cable **220** as shown at FIG. **73**, the central portion **1002** fits within the buffer tube **222** with the closed side **1005** positioned adjacent a bottom side of the buffer tube **222** and the open side **1004** positioned at the cut region **270**. Also, the pass-through axis **1011** of the channel **1003** is generally parallel to a central axis **1009** of the buffer tube **222**, and the ribbon stack **225** of the cable **220** passes through the channel **1003**. Reinforcing arms **1007** project outwardly from the central portion **1002**. The reinforcing arms **1007** have a curvature **1008** that generally matches an outer diameter of the cable jacket **230**. When the reinforcing member **1000** is mounted to the cable **220** at a breakout location, as shown at FIG. **73**, the arms **1007** extend around at least a portion of the outer diameter of the cable jacket **230** and assist in preventing the cut region **270** from collapsing. It will be appreciated that one or more of the reinforcing members **1000** can be used to reinforce cable **220** at the cut region **270**. In the embodiment of FIG. **74**, a plurality (e.g., 6 or more) of the reinforcing members **1000** are uniformly spaced along the length of the cable **220** that coincides with the cut region **270**. In this way, the breakout location includes segmented reinforcement with areas of reinforcement axially separated by areas of flexibility **1111**. In FIG. **75**, overmold **450** is shown enclosing the breakout location.

At a given breakout location, it has been determined that fibers $\mathbf{224}_{dc}$ accessed from the ribbon stack **225** as well as the tether fibers $\mathbf{224}_t$ spliced to the fibers $\mathbf{224}_{dc}$ can become pinched or otherwise damaged at the cut region **270**. To prevent this from occurring, the fibers $\mathbf{224}_{dc}$, $\mathbf{224}_t$ can be secured/bundled to the ribbon stack **225** to assist in keeping the fibers $\mathbf{224}_{dc}$, $\mathbf{224}_t$ within the interior of the buffer tube **222** for most of the length of the cut region **270**. As shown at FIG. **74**, a securing member **1010** (e.g., a spiral wrap, a tape, a film or other structure) is used to secure the fibers $\mathbf{224}_{dc}$, $\mathbf{224}_t$ to the ribbon stack **225** along the length of the cut region **270** up to the point where the fibers $\mathbf{224}_t$ are routed from the interior of the buffer tube **222** to the block **704**.

Various breakout configurations in accordance with the principles of the present disclosure are adapted to allow any of the fibers of the ribbon stack **225** to be accessed for splicing to a tether fiber $\mathbf{224}_t$ regardless of whether the ribbon fiber desired to be accessed is at the top, bottom or middle of the ribbon stack **225**. Referring to FIG. **73**, the ribbon stack **225** has a width W**1**, a height H and a maximum cross-dimension CDmax. To facilitate accession any of the fibers of the ribbon stack, the cut region **270** is provided with a width W**2** that is larger than the width W**1**. It is preferred for the width W**2** to be greater than the width W**1** along the entire length of the cut region **270** (e.g., see the embodiment of FIG. **4**). By sizing the width W**2** larger than the width W**1**, the ribbon stack **25** can be manually pulled through the cut region **270** to facilitate accessing any fiber of the ribbon stack desired to be accessed. Referring again to FIG. **73**, the minimum cross-dimension CDmin defined by the channel of the buffer tube **222** is preferably greater than the maximum cross-dimension CDmax defined by the ribbon stack **225** to allow the ribbon stack **225** to be manually twisted/rotated about its central axis within the buffer tube **222** when the fibers $\mathbf{224}_{dc}$ are being accessed. This allows the ribbon stack **225** to be manually twisted within the buffer tube **222** to facilitate pulling the ribbon stack **225** through the cut region **270** and to facilitate accessing any of the fibers of the ribbon stack regardless of whether they are on the top (i.e., facing toward the cut region), bottom (i.e., facing away from the cut region) or middle of the ribbon stack. In the embodiment of FIG. **73**, the buffer tube **222** has a circular transverse cross-section with the minimum cross dimension CDmin being defined by the inner diameter of the buffer tube **222**.

As used herein, when the fibers $\mathbf{224}_{dc}$, $\mathbf{224}_t$ have been spliced together, the fibers $\mathbf{224}_{dc}$, $\mathbf{224}_t$ can collectively be referred to as an optical fiber structure. In such a case, the optical fiber structure includes a first length of optical fiber within the distribution cable, a second length of optical fiber that extends through the breakout location and a third length of optical fiber that extends through the tether. The first, second and third lengths are in optical communication with one another so as to define a signal path that extends from the distribution cable, through the breakout location, to the end of the tether. The term optical fiber structure also includes lengths of optical fibers that do not include intermediate splices (e.g., a spliceless breakout). As used herein, the term "breakout portions" of optical fiber include portions of optical fiber that extend along the length of a breakout location. Breakouts in accordance with the present disclosure can be enclosed/sealed for outside environmental use. For example, sealing structures such as overmolds, heat-shrink tubes, heat-shrink tape/wrap or other sealing structures can be used.

The above specification provides examples of how certain inventive aspects may be put into practice. It will be appreciated that the inventive aspects can be practiced in other ways than those specifically shown and described herein without departing from the spirit and scope of the inventive aspects.

We claim:

1. A telecommunications cable comprising:

a main cable including a cable jacket and a central buffer tube positioned within the cable jacket, the central buffer tube defining a buffer tube passage, the main cable also including a ribbon stack positioned within the buffer tube passage, the ribbon stack including a width, a height and a maximum cross-dimension, the buffer tube passage having a minimum cross-dimension, the main cable including a cut region where a slot has been cut through the cable jacket and the central buffer tube to provide access to the ribbon stack during manufacture of the telecommunications cable, the slot having a length and a width, the width of the slot being larger than the width of the ribbon stack, the minimum cross-dimension of the buffer tube passage being larger than the maximum cross-dimension of the ribbon stack, and a portion of the cable jacket extending continuously across the cut region along the length of the slot;

a tether that branches from the main cable at the cut region;

an optical fiber structure that extends from the ribbon stack, through the cut region and into the tether; and

an enclosure covering the cut region.

2. The telecommunications cable of claim **1**, wherein the buffer tube passage is circular, and wherein the minimum cross-dimension of the buffer tube passage equals an inner diameter of the central buffer tube.

3. The telecommunications cable of claim **1**, wherein the slot that has been cut through the cable jacket is rectangular.

4. A telecommunications cable comprising:

a main cable including a cable jacket and a central buffer tube positioned within the cable jacket, the central buffer tube defining a buffer tube passage, the main cable also including a ribbon stack positioned within the buffer tube passage, the main cable including a cut region where a slot has been cut through the cable jacket and the central buffer tube to provide access to the ribbon stack during manufacture of the telecommunications cable, the ribbon stack including at least an accessed optical fiber that is accessed at the cut region, and a portion of the cable jacket extending continuously across the cut region along a length of the slot;

a tether that branches from the main cable at the cut region, the tether including a tether buffer tube surrounding at least a first optical fiber of the tether, the first optical fiber of the tether being optically coupled to the accessed optical fiber of the ribbon stack at a coupling location located inside an outer boundary defined by the cable jacket; and

a securing structure that binds the accessed optical fiber and the first optical fiber of the tether to the ribbon stack within the buffer tube passage.

5. The telecommunications cable of claim **4**, wherein the securing structure includes a film that wraps around the accessed optical fiber and the first optical fiber and that prevents the accessed optic fiber and portions of the first optical fiber of the tether from moving outside the central buffer tube and into the cut region.

6. The telecommunications cable of claim **4**, wherein the slot that has been cut through the cable jacket is rectangular.

7. A telecommunications cable comprising:

a main cable including a cable jacket and a central buffer tube positioned within the cable jacket, the central buffer tube defining a buffer tube passage, the main cable also including a ribbon stack positioned within the buffer tube passage, the main cable including a cut region where a slot has been cut through the cable jacket and the central buffer tube to provide access to the ribbon stack during manufacture of the telecommunications cable, the ribbon stack including at least an accessed optical fiber that is accessed at the cut region;

a tether that branches from the main cable at the cut region; and

a reinforcing member for reinforcing the main cable at the cut region, the reinforcing member including a central portion positioned within the buffer tube passage, the central portion defining a channel through which the ribbon stack is routed, the reinforcing member also including arms that project outwardly from the central portion and extend around at least a portion of an exterior of the cable jacket.

8. The telecommunications cable of claim **7**, wherein the main cable is reinforced by a plurality of the reinforcing members that are spaced apart along a length of the main cable coinciding with the cut region.

9. The telecommunications cable of claim **8**, further comprising an elongate jacket support that covers the slot in the cable jacket and includes legs that fit inside the channels defined by the central portions of the reinforcing members.

10. The telecommunications cable of claim **9**, wherein the tether includes a tether fiber that is spliced to the accessed optical fiber of the ribbon stack at a location beneath the elongate jacket support.

11. The telecommunications cable of claim **10**, further comprising a block mounted to the main cable at one end of the cut region, the tether being anchored to the block and the block functioning to transition the tether fiber from the tether to the cut region.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,840,109 B2
APPLICATION NO. : 12/180670
DATED : November 23, 2010
INVENTOR(S) : Yu Lu et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

In Column 4, Line 28:
"fiber/yam" should read -- fiber/yarn --

Signed and Sealed this
Third Day of October, 2017

Joseph Matal

Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office